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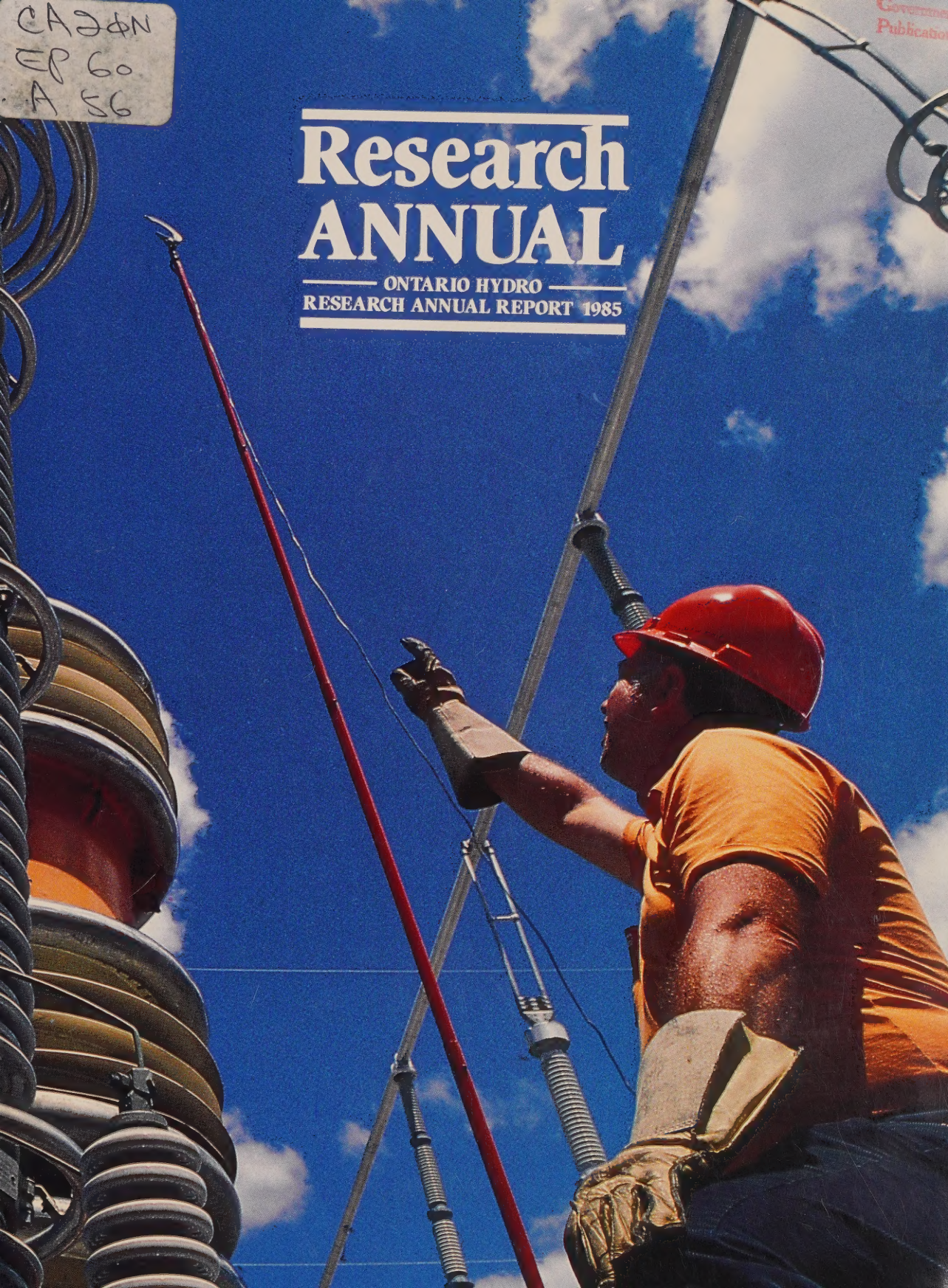
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Research ANNUAL

— ONTARIO HYDRO —
RESEARCH ANNUAL REPORT 1985





The photo shows a mobile 700-kV resonant reactor system and its voltage divider being prepared for overvoltage tests to verify the integrity and reliability of SF₆-insulated bus-duct and switchgear at Claireville Transformer Station. This station, located just northwest of Metropolitan Toronto, is a key point in Ontario Hydro's growing 500-kV transmission system that carries power from large generating complexes, such as the Bruce Nuclear Power Development and the northern hydro-electric generating stations on the Abitibi and Mattagami Rivers to connections with the 230-kV system and load centres in southern Ontario.

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Vice-President's Message

Ontario Hydro is one of the largest electrical utilities in the world and one of the best in terms of efficiency, economy and reliability. Its power system includes hydro-electric, fossil-fired and nuclear-fuelled generating stations with a total dependable capacity of 24 291 megawatts, and a delivery system that extends throughout most of the inhabited parts of the province. In 1985, the Corporation used these facilities to make available 109 million megawatt hours of electricity for distribution with the cooperation of 316 municipal utilities to about 3 165 000 ultimate customers.

Ontario Hydro does more than just maintain and operate its power system. It also undertakes much of the design and construction necessary to meet growth in requirements and to replace obsolete facilities. The Research Division provides technological leadership and support and is often involved in the development and application of devices and processes that are specifically designed to meet Ontario Hydro requirements. Many of these applications involve Ontario industry and some find markets elsewhere, creating revenue and jobs.

The transfer of technology between Hydro and industry has been going on since Ontario Hydro was founded in 1906 and has greatly benefited the province. A number of transfers in which the Research Division has participated are described in the pages that follow. One, the OH-180 programmable controller, is featured on page 44.

L.G. McConnell

L.G. McConnell
Vice-President
Power System Program



Director's Message



nineteen eighty five
by a number of events of
major significance to the
Research Division

New facilities were commissioned to test, evaluate and demonstrate new technologies and processes for utilization of energy. This aids our customers by providing a basis for decision with respect to new technologies that promise improvements in energy economy and product quality. Among the more important of these technologies are applications of infrared and microwave radiation for drying and heating, and the use of plasma arcs in the production of spherical ceramic particles suitable for sintering.

With the cooperation of the Human Resources Branch, Division management finalized development and obtained approval for implementation of a "ladder" concept. This provides senior scientific and engineering staff with the option of a career course that frees them to pursue technical objectives without hindrance from administrative responsibilities.

In addition, 1985 saw the establishment of an awards program intended to recognize outstanding contributions by laboratory staff in the fields of technology and management. The program commemorates the contributions of the men for whom two of the awards were named - Dr. W.P. Dobson, pioneer Director of Research, and Dr. H.A. Smith, who oversaw development of Ontario Hydro's nuclear program.

During the year the Division continued to provide the usual high calibre of support to Ontario Hydro in meeting and resolving problems encountered in the ongoing operation of the power system. I am pleased to record my appreciation of the dedication and hard work of the Division's managers and staff.

F.J. Kee
Director of Research

Research Departments

Support functions required for smooth operation of the Division are provided under the guidance of J.B. (Bruce) Brown, manager of the **Divisional Services Department**. These include accounting, secretarial, clerical, word processing, photographic and editorial services. Technical support is supplied by a drafting office and a model shop.

O.A. (Allan) Kupcis, manager of the **Chemical Research Department**, oversees research in the chemical, biological and environmental disciplines. Work ranges from provision of analytical chemical services to investigation of methods for control of acid rain and other pollutants.

T.W. (Tony) Klym, manager of the **Civil Research Department**, is responsible for research, testing and inspection involving soils, rock and concrete. Activities include engineering assistance in the selection of sites for new facilities, optimization of the strength and durability of concrete, and evaluation of the mechanical properties of large rock masses.

Identification of new research opportunities and initiation and coordination of research activities within the Division and in collaboration with outside organizations are two important functions of the **Divisional Projects Department** managed by J.G. (Jack) Cassan.

Mr. Cassan also acts as manager of the **Operations Research Department**,

which provides consulting services to all units of Ontario Hydro in areas of operations research, statistics and reliability assessments. This Department also provides computer support services to the Division.

A.F. (Anton) Baljet manages the **Electrical Research Department**. The work of this group ranges from the solution of problems affecting the operation of the power system to studies of new and efficient uses of electrical energy. New applications of electronics in the power system are developed.

The **Mechanical Research Department**, managed by G.J. (Gord) Clarke, is responsible for improving the performance, reliability and safety of components and mechanical processes used in the generation, transmission and distribution of electricity. The work includes studies of machine dynamics, and full-scale testing and stress analyses of structural components.

Under the leadership of J. (Jim) Brown, the **Metallurgical Research Department** explores many areas of physical metallurgy and materials science. Work includes evaluation of the integrity of components in nuclear and thermal plants, corrosion studies, fracture mechanics analyses, and nondestructive testing and evaluation.



DIVISIONAL SERVICES
J.B. (Bruce) Brown



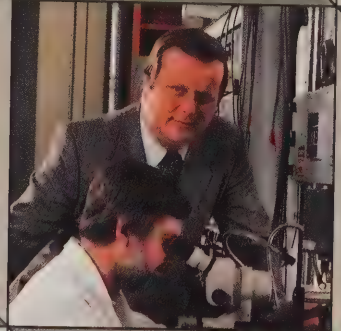
CHEMICAL
O.A. (Al) Kupcis



CIVIL
T.W. (Tony) Klym



ELECTRICAL
A.F. (Anton) Baljet



METALLURGICAL
J. (Jim) Brown



DIVISIONAL PROJECTS
J.G. (Jack) Cassan



MECHANICAL
G.J. (Gord) Clarke



Ontario Hydro is fortunate to have a large, diverse and effective resource of generating facilities. In 1985, the Corporation generated 115 824 000 MW·h of electricity - 48 459 000 MW·h at nuclear stations, 29 941 000 MW·h at fossil-fired stations and 37 424 000 MW·h at hydraulic stations.

The nuclear units are of the CANDU design, and for some years they have held most of the top places for gross capacity factor among the world's large power reactors. They generate energy at low cost, their safety record is good and their radiation emissions are well below the limits set by regulatory authorities. The efforts of the Research Division are directed towards maintenance of this high degree of nuclear unit effectiveness.

Modern fossil-fired units are of large dimensions to obtain economies of scale, and a small defect can cause a large and costly power outage. The Research Division is responsible not only for helping to solve problems as they occur but also for performing studies aimed at avoiding unit failures.

In hydraulic plants, design changes have been less frequent and problems may be fewer for that reason. The main function of the Division in this area is to provide support for the maintenance and repair of existing equipment and structures.

NUCLEAR

Characteristics and Performance of CANDU Pressure Tubes

Investigation of the mechanism by which hydride blisters form on the pressure tubes of fuel channels in CANDU reactors continued in 1985. Laboratory tests and large-scale loop tests showed that hydride blisters can form on pressure tubes made of Zr-2.5wt%Nb as well as those made of Zircaloy-2, the alloy used in the pressure tube of Unit 2 at

Pickering NGS that failed in 1983. A computer model was developed by the Research Division to predict the growth of blisters on pressure tubes in contact with calandria tubes at various stages of reactor life.

To verify the thermal calculations of this model, an apparatus has been developed that brings a sample section of pressure tube into contact with a surrounding section of calandria tube, also made of zirconium-niobium alloy. The pressure tube is deformed as necessary to provide the desired area of contact. Reactor operating conditions are simulated by circulating oil at about 300°C on the primary side and water at 60°C on the secondary side. A technique which permits installation of thermocouples in small-diameter holes as close as 0.127 mm to the contact surface has been developed and used. This allows measurement of transient and steady-state temperatures with minimal effects on the thermal field.

Blister formation, however, is only one aspect of the integrity assessment. It is necessary to know also if the blisters will initiate cracks. Studies are therefore in progress to establish the stress levels at which cracks will initiate from blisters of various sizes.

The extent of pressure-tube calandria-tube contact and the amount of hydrogen in the bulk of the pressure tube, which depends on operating time and rate of corrosion, are of primary importance in blister formation. Extensive study of Zr-2.5wt%Nb was initiated as there is little available information on the corrosion characteristics of this alloy. Post-service examinations of pressure tubes are now being made at regular intervals and a computer data base has been established to record all data from this source.

Elongation of pressure tubes will require extensive maintenance in some reactors and there is a possibility that changes in reactor operating conditions could lead to an increase in deformation rate that would limit pressure-tube life. Extensive irradiation-growth tests on different Zr-2.5wt%Nb pressure-tube materials have therefore been performed in the Dido reactor at AERE Harwell, in

Full-scale tests of very large pumps and pump motors can be performed in the Division's Nuclear Process Components Test Facility.

which the fast neutron fluence is higher than in power reactors. The results of this study indicated that there is a need for change in the predictive design equation and will provide the basis for that change.

Location and Repositioning of Fuel-Channel Spacers

Garter springs are used to maintain proper spacing between the pressure tubes and surrounding calandria tubes of the fuel channels in CANDU reactors. During assembly and operation, these spacers may move away from their design locations and this can have adverse effects on the service-life of the unit. The development of means for fuel-channel Spacer Location and Repositioning (SLAR) is therefore highly important.

The garter springs are located with the use of classical eddy current probes.

A novel electrical device, based on the principle of the linear induction motor, has been developed for moving garter springs to desired locations on the fuel channels of reactors that are commissioned but not operating. This is the key component of the SLAR system; it provides the only way to reposition the garter springs under the stringent SLAR conditions.

The latest prototype operates at low power levels (208 V, 100 A, 60 Hz) in a wet channel with the fuel removed. A set of two of the devices has been built and incorporated into SLAR tooling for field use. The SLAR technology may be useful in CANDU reactors throughout the world.

A fully automated ultrasonic device which permits very rapid inspection of a limited part of the tube has been developed as part of the SLAR system. This detects the presence of hydride blisters at pressure-tube - calandria-tube contact zones.

Remote Inspection and Gauging of Pressure Tubes

Development of the fuel Channel

Inspection and Gauging Apparatus for Reactors (CIGAR) has been completed. The apparatus measures the diameter and wall thickness of each tube at many locations, plots the sag profile of the tube, locates the garter-spring spacers and inspects the tube ultrasonically for flaws.

The CIGAR system provides Ontario Hydro with a number of new and significant inspection capabilities. Central Nuclear Services used the device to inspect 20 pressure tubes in an operating reactor at Pickering NGS during a 10-day period. The technology was also applied during an inspection of Pickering NGS Unit 8 pressure tubes after it was discovered that fretting by dummy fuel bundles had marked the inside surface. Development and application of methods of mapping the damage showed that if subsurface defects developed, they could be detected and distinguished from the surface damage.

Large-Scale Fuel-Channel Replacement

The Large-Scale Fuel-Channel Replacement (LSFCR) program is now under way for CANDU Units 1 and 2 at Pickering NGS. As part of this program, the Research Division has developed a fast induction heating technique for separating fuel-channel pressure tubes from their rolled joints with end fittings. With use of this technique, one end-fitting is retained undamaged on each tube. Without it, both end-fittings would have to be destroyed. The technique therefore produces a significant cost saving for Ontario Hydro and could ultimately be of substantial benefit to other CANDU owners.

The need for staff participation in LSFCR makes reduction of radiation fields in primary-heat-transport systems highly important. The CANDECON process, developed for this purpose by AECL in cooperation with Ontario Hydro, was successfully performed on Units 1 and 2 at Pickering NGS in 1984. Work continues to improve understanding of corrosion that occurs under CANDECON conditions and to lessen its effects.

Corrosion of Steam Generator Tubes

A major threat to the integrity of nuclear steam generator tubes is localized corrosion under sludge piles that accumulate on tubesheets. Contaminants normally present at low levels in steam-generator feedwater were found to be present at high concentrations in sludge from Pickering NGS. Electrochemical methods and laboratory autoclave studies were used to determine the nature and extent of corrosion under the sludge at steam-generator temperatures and pressures.

Scaling behaviour and corrosion in actual steam-generator water are being studied in autoclaves at Bruce NGS. Specially constructed probes are being used to determine the effect of stress on the corrosion process.

Two treatments are under development for the removal of sludge from in-service steam generators: chemical cleaning for Bruce NGS and high-pressure water jetting for Pickering NGS. This year a specific solvent composition for chemical cleaning was recommended. Studies continued of the effectiveness of water-jetting in lancing the sludge deposits with minimal damage to the tubes.

Factors affecting the deposition of magnetite particles and other materials on steam-generator surfaces are being studied. A model boiler test loop is being used to evaluate alternative pH and oxygen control agents that will minimize corrosion in condensate and feedwater systems and thereby reduce the ingress of corrosion products to the steam generators.

Corrosion of Heat Exchanger Tubes

A rig for corrosion testing of heat-exchanger-tubing alloys has been built at Pickering NGS to gain a fundamental understanding of the initiation and propagation of localized corrosion of tubes by Lake Ontario water. Immersion and electrochemical tests have identified alternative tubing alloys that have greater resistance to pitting in lake water than materials now in use.

Heavy Water Purification

Programs to improve technology for purification of heavy water in the primary-heat-transport and moderator systems of CANDU reactors are continuing. Detailed procedures for quality-assurance tests of resins used in the purification circuits of these systems have been developed and made available to help manufacturers to supply resins of appropriate quality.

Leak-Before-Break Characteristics of Materials

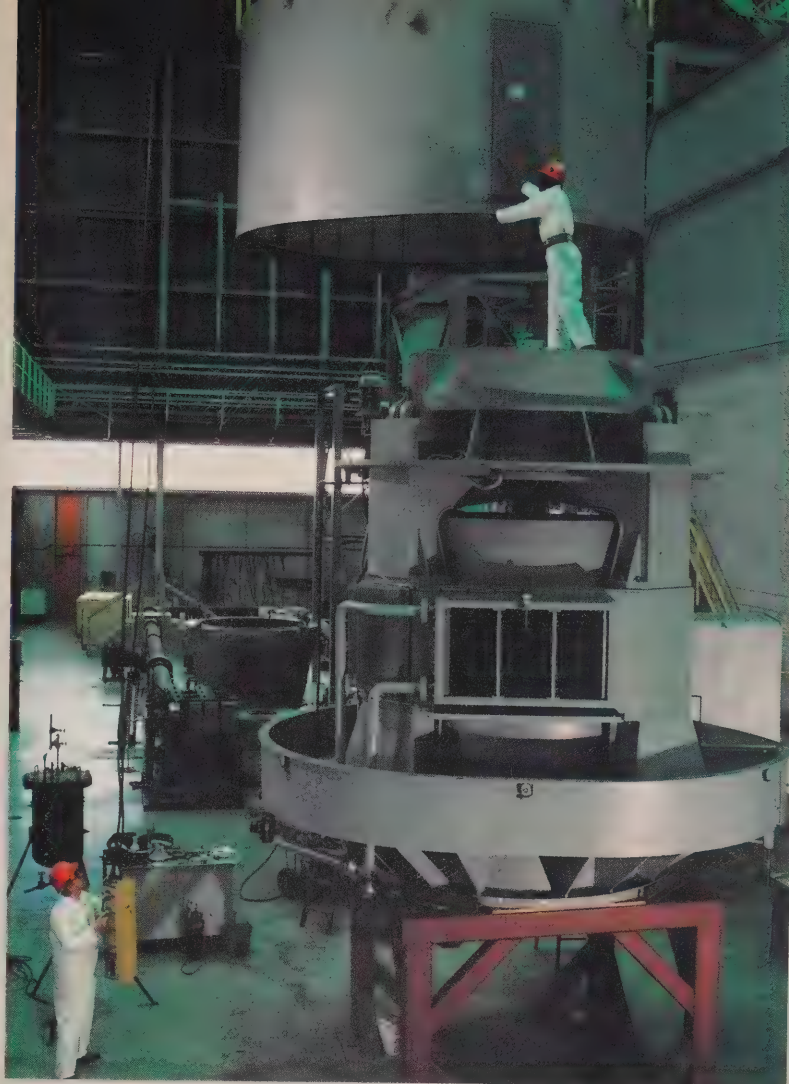
In cooperation with the ASTM, the Research Division has developed standard methods for measuring the ductile-fracture properties of steels. The measurements are being used to produce a data base of ductile-fracture properties in steels for piping in the Darlington NGS Primary-Heat-Transport (PHT) system.

In concurrent work, new concepts in elastic-plastic fracture mechanics have been applied in numerical simulation of the non-linear mechanical response of PHT system components to service loads. This will be used in conjunction with the material data base to assess the severity of cracks in PHT piping that are postulated for design purposes.

These projects are part of a joint leak-before-break program of the Research, Design and Development and Nuclear Studies and Safety Divisions to demonstrate the structural integrity of the Darlington NGS PHT system without modification to include pipewhip restraints.

Testing of Nuclear Process Equipment

Tests were completed on a Darlington NGS primary-heat-transport pump-motor set to determine the behaviour of the machine under two-phase, steam – water flow conditions that simulated a small-break Loss-Of-Coolant Accident (LOCA). The results confirmed the ability of the machine to tolerate rough operation without damage during LOCA conditions, and provided data on pressure pulsations for use in analysis of plant piping integrity.



A primary-heat-transport pump-motor for Darlington NGS is being disassembled for inspection after performance and endurance testing in the Nuclear Process Components Test Facility.

A modified version of a large isolation valve for the Bruce NGS emergency coolant injection system was also tested. Operation of the valve through many cycles over the full range of expected operating conditions showed the need for further improvements and retesting.

Work on the testing of nuclear station equipment was broadened to include qualification of electrical instrumentation and control components under the harsh conditions that could result from a postulated break in heat-transport primary circuits or steam lines. The environmental chamber now in use for tests on such components as cables, terminal boxes, switches and solenoid valves is being upgraded to handle larger components over a wider range of test conditions.

Refilling and Rewetting of Hot Horizontal Tubes

A need exists for a better understanding of the effects of refilling and rewetting hot horizontal tubes like those that might be found in a CANDU reactor under LOCA conditions. This has prompted a study that uses an experimental facility consisting of a horizontal, directly heated Zircoloy-2 tube, a water-injection system, and instruments for measuring void fractions, pressures and wall temperatures. Subcooled water is injected into the tube which has been heated uniformly to a desired initial temperature in the range from 300° to 600°C. Thermodynamic parameters are logged during each quench until steady state conditions are obtained.

The data obtained in this way have been used by AECL to verify the heat transfer part of the advanced thermodynamic code, ATHENA. Detailed wall-temperature measurements permit better estimation of inner-surface temperatures and heat-flux during the quench transient. The resulting heat-flux versus inner-surface temperature curve, termed the quench curve, may have significant effect in LOCA analysis.

Thermal Gradients and Tension Stiffening in Reinforced Concrete

A joint study by Civil Design and Civil Research of thermal gradient effects in reinforced concrete structures is providing data needed to improve current analytical techniques and to address questions related to the design, performance and safety of Ontario Hydro's nuclear containment structures.

Specifically, the thermal gradients encountered in LOCA conditions are simulated.

Test data from the first thermal-gradient model indicated that current analytical procedures give fairly good predictions of the response of members to thermal gradient loading, but tend to over-estimate the stiffness of cracked members and make inadequate provision

Workmen are finishing the installation of post-tensioning ducts and reinforcing bars of the vacuum building at Darlington NGS. Thermocouples and strain gauges were attached to the bars prior to concrete placement to permit research engineers to measure responses under test and operation conditions.



for concrete creep. Testing with a second thermal gradient model began in November 1985.

A research program has been undertaken to investigate tension-stiffening mechanisms, which significantly affect the response of reinforced-concrete structures to service loads. Three large-scale beam specimens have been built and tested with the beams in axial tension.

The program will support analysis of the performance of Ontario Hydro's nuclear containment structures under postulated LOCA conditions. The containments have been designed not to approach yield conditions even in such an extreme situation. The availability of a rational constitutive model for tension-stiffening mechanisms would permit analysis to determine the effective stiffness of the loaded members, the magnitude of the forces induced, and the crack patterns and subsequent redistribution of forces.

Decontamination of Spent-Fuel Storage Baskets

The decontamination of obsolete stainless-steel spent-fuel storage baskets from the irradiated fuel bay of Pickering NGS 'A' may lead to considerable

savings in storage costs if the baskets can be decontaminated to a point where they can be disposed of as metal scrap. The search for a suitable chemical decontamination method has led to specification of a process based on a dilute aqueous solution of nitric and hydrofluoric acids. Application of this reagent to basket surfaces in laboratory trials yielded satisfactory results.

Recovery of Carbon-14 from Moderator Cover Gas

Most of the carbon-14 present in the moderator cover gas of CANDU reactors is released to the atmosphere in low concentrations during purging of the cover gas and other maintenance activities. With AECL's approval, a prototype scrubber for removal of carbon-14 from gas streams by adsorption on solid calcium hydroxide has now been designed for demonstration in 1986. The concept has been approved by the Atomic Energy Control Board and could be retrofitted to any CANDU reactor operating in Canada or abroad.

In related studies, a prototype cryogenic still has been completed to demonstrate the concentration of carbon-14 extracted from moderator cover gases and spent ion-exchange resins. If carbon-14 is

enriched to a concentration above 90 per cent, a troublesome, long-lived nuclear waste becomes a valuable commercial byproduct.

Flammability and Integrity of Station Control Cables

A fire test developed by Ontario Hydro has been adopted by CSA and in the National Building Code as the standard for evaluation of the flammability of grouped electrical and communications cables used in the control systems of nuclear generating stations. Cable-fire barriers have also been developed to minimize the migration of smoke and corrosive and toxic gas byproducts into station computer rooms and other sensitive areas during a fire.

Examination and tests of cable samples from Pickering NGS 'A' have shown negligible degradation of the cables after 15 years of service. Laboratory aging of the samples revealed that the cables would still be functional after a further 20 years of service.

Detection of Leaks in Nuclear Containment Structures

To retain their operating licences, proprietors of nuclear plants must achieve high standards of air tightness in reactor buildings and other containment structures. At present, leak detection solutions are the only effective means of locating air leaks in these structures. In research funded by COG, new tools based on ultrasonics and use of SF₆ as a tracer gas are being developed to achieve remote as well as quantitative detection of leakage.

Tritium Technology

Design and engineering of the Tritium Immobilization System (TIS) has been completed for the storage of pure tritium gas on a metal 'sponge'. The TIS will be part of the tritium removal facility being installed at Darlington NGS and is expected to find commercial application in other tritium handling processes.

A model of hydrogen permeation and recycling in Tokamak devices has been

The Cryogenic Chamber at the Tritium Removal Facility of Darlington NGS is undergoing its final inspection before it is sealed. Hydrogen gas is separated into its protium, deuterium, and tritium components by distillation at 20 K.



developed and experimentally verified. Applications based on the property of asymmetric permeation in composite materials have been identified. These include tritium pumping and passive fuel purification. A prototype tritium pump, with no moving parts, has been designed and is being fabricated. Experiments conducted in Germany have verified the pump concepts. The concept of asymmetric permeation for experimental fusion devices has significant potential for commercial exploitation.

A compact, versatile gas chromatographic system has been developed for separating tritium and deuterium species from the purified exhaust gas streams of experimental fusion reactors. The system is intended to feed the separated species back into the fuel stream of the reactor. A prototype of the system has been completed which processes 1.7 litres of exhaust gases per hour, a capacity that suits the fuel-system recycling requirements of many present-generation experimental fusion reactors.

Sorption rates of tritium gas and tritiated water into four protective coatings and desorption rates from them were measured. While desorption of tritium gas is extremely fast, retention of tritiated water by the coatings is significant. This may have a major influence on decontamination procedures adopted for tritium removal and storage facilities. Epoxy mixes with a high pigment-to-binder ratio appear to be the best coatings for concrete used in tritium handling facilities.

THERMAL

Corrosion Problems in Thermal Plants

Laboratory testing has shown that failures of brass tubing in low-pressure feedwater heaters at Nanticoke TGS were initiated by a flow-assisted electrochemical corrosion process accelerated by the effects of elevated temperatures and high levels of dissolved oxygen, carbon dioxide and ammonia in the feedwater. Since the replacement of morpholine by ammonia for feedwater pH control in all units at Nanticoke TGS,

tube corrosion has been significantly reduced.

Chemical treatments have been developed to reduce exfoliation of oxide scale from steam-exposed surfaces in superheaters and reheaters. Uncontrolled release of exfoliated scale can lead to serious mechanical damage to turbine equipment. The results of laboratory tests have shown that when tubes are treated with borate solutions the growth rate of steamside scale is slowed, scale adhesion increases and exfoliation decreases. In-situ evaluation of treated tubes will be continued for three years at Lambton TGS to assist with further development of measures for exfoliation control.

Corrosion-Fatigue in Carbon-Steel and Zirconium-Alloy Tubing

Corrosion-fatigue cracking in the carbon-steel tubing of fossil-fired boilers is being investigated in a project funded as part of an EPRI program. Various relevant boiler-water-chemistry conditions will be controlled inside tube samples and their effects monitored while the tubes are subjected to cyclic mechanical loads. A second facility is being set up to study the corrosion-fatigue susceptibility of carbon-steel and Zr-2.5wt%Nb tubing in CANDU units.

Life of Tubular Components Under Creep Conditions

Tubular components of various sizes and wall thicknesses, both with and without weldments, are being tested under isothermal and cyclic conditions over a range of internal pressures and tensile end loads. Factors affecting crack initiation and growth are being examined with a view to developing a quantitative relationship for life prediction.

Cleaning of Coal by Oil Agglomeration

In work funded by EPRI, the effectiveness and economics of spherical oil agglomeration were evaluated for the cleaning of coal to very low impurity levels. This process achieves high rates of recovery of coal fines from the cleaning-plant refuse stream. Bench and

pilot-scale experiments have identified the optimum process conditions required for the production of clean-burning coal.

HYDRAULIC

Repair of Turbine Cavitation Damage

Erosion of turbine runners by cavitation is of major concern to operators of hydraulic generating facilities. Periodic repair of the damage involves gouging and grinding to remove unsound metal, then arc welding and final grinding to restore the original surface profile. This work is often done in-situ where access is difficult and working conditions are hazardous.

Ontario Hydro Research and IREQ are now engaged in a CEA-supported program to develop robotic methods and equipment for cavitation repairs. IREQ is optimizing equipment and controls for use with compact robots in the gouging operation and Ontario Hydro Research is adapting recently developed technology in surface mapping and automated welding for use in the repair process. When completed, the process will include robotic profile grinding as well.

Performance of Concrete Hydraulic Structures

Fourteen concrete dams were visited to collect information on their condition after long periods of service in saturated conditions. The findings are being correlated with past records of accelerated laboratory tests and outdoor exposure tests of concrete specimens of various mix designs. The work is expected to result in improved test procedures for predicting the long-term performance of concreting materials for use in new structures and for repair of existing ones.

Monitoring Concrete and Rock Structures

Inverse and normal pendulums and wire extensometers are being installed for monitoring the long-term performance of dams at Abitibi Canyon, Little Long, Harmon and Kipling Generating Stations. Techniques for fabricating and installing the devices and interpreting the



The casing for a sliding micrometer is being installed to monitor the minute movement of a rock cliff above a generating station as part of a program to protect the station's structure and equipment from falling debris.



measurements were provided by Hydro-Quebec and a Swiss utility.

Monitoring of in-situ deformation in rock cliffs along the Niagara River gorge was begun in cooperation with a Swiss firm. Deformation is measured along a horizontal borehole by a sliding micrometer to an accuracy of $3 \mu\text{m}$ per 1 m of observed length. An extremely sensitive tool, the sliding micrometer also identifies active joints in the cliffs. This system has the highest resolution of any of its type in Canada, and interest in its use has been shown by AECL and Hydro-Quebec. Further use of the system is planned for several Ontario Hydro dams.

Research Division staff conduct surveys and inspections as part of a program to maintain the integrity of many old concrete structures. Rehabilitation work is shown underway on the 87-year-old intake structure that supplies water to DeCew Falls GS on the Welland Canal.

OTHER STUDIES

Modelling of Large Synchronous Generators

In simulation studies to determine power-system operating limits, models of system components, such as generators, excitation systems and speed governing systems, must accurately represent the equipment used in the field. System components are therefore tested intensively to acquire data for modelling.

In 1985 the standstill frequency response method of testing two- and four-pole synchronous machines, a technique pioneered by Ontario Hydro, was made a trial-use standard of the IEEE. A CEA contract in which five large turbine generators at various locations across Canada were tested by this technique was completed.

A method to better approximate the steady-state operating conditions of a unit promises substantial economic benefits

by allowing use of a little more of the generation that has been "locked-in" at Bruce NGS as a result of delays in transmission-line construction. Tests have been completed on two Bruce NGS units, and payback is expected in 1986.

Surge Protection of Generators

In a project funded by EPRI, the Research Division is making a detailed investigation of the surge environment at the terminals of large synchronous generators. The recent trend towards use of generator breakers has added a number of new mechanisms for possible switching transients. Models based on field tests are being developed for simulating unusual or potentially hazardous system conditions. The surge-withstand capabilities of generators are also being examined, as is the current practice of generator surge protection. The results of this project will affect the design of future generating stations and could lead to modification of current operating practices.

Large generators and motors are integral parts of the process of producing electricity. Non-contact transducers are used to measure shaft vibration and thrust-bearing oil-film thickness as part of a new computer-automated "Monitoring for Predictive Maintenance" system that is intended for use in planning maintenance of the hydraulic generators at the Sir Adam Beck - Niagara GS.



Power System Stability

Continuing delays in the construction of transmission lines, the commissioning of additional generation and the need to maintain export capability make improvement of power-system stability an increasingly critical requirement.

The latest in power system stabilizers, which work through the excitation system of the generator, are being commissioned at Bruce NGS as units are brought into service. Similar stabilizers are being supplied for the Darlington generators. Without these control systems, there would be substantially more 'locked-in' generation at the Bruce NGS and power export capability would be restricted.

Controls that enhance transient stability have been developed and applied to nuclear units at Bruce NGS and coal-fired units at Nanticoke TGS as a means to further improve system stability. These controls act through the excitation systems to maintain a higher than normal terminal voltage on the generator for about one second after a major system fault.

The State Electricity Commission of Western Australia (SECWA) has purchased four of Ontario Hydro's power system stabilizers. These are being installed on existing fossil-fired units and commissioned with the assistance of Research Division personnel. The use of these stabilizers on the SECWA system has the effect of making the stability of their system insensitive to variations in system load characteristics.

Computer-Managed Monitoring of Rotating Machinery

The Research Division has developed a computer-managed system for monitoring vibration of rotating machinery to detect deterioration at an early stage and identify probable causes. The system will use a total of 508 sensors on 124 pumpsets in four CANDU nuclear units. It will make base-line comparisons, generate trend plots and perform pumpset condition analyses. Diagnostic logic incorporated in a knowledge-based system will automate the decision-making process

that a vibration analyst would follow in evaluating a set of vibration signatures.

The system will reduce pumpset maintenance costs and improve plant availability at Darlington NGS, now under construction. With development of the necessary knowledge-base, it could be adapted to monitor other rotating machinery.

Improved Facilities for Seismic Testing of Station Equipment

Two tri-axial shakers are now available for the seismic qualification of small- and medium-size nuclear plant equipment. Two new environmental chambers are being commissioned for accelerated aging of test specimens to accommodate a shift

in emphasis to seismic testing of artificially aged rather than new equipment.

Following guidelines set by the Sandia National Laboratories in the United States, the performance of new and aged station batteries was evaluated before, during and after seismic testing. Conditions were representative of the strongest earthquakes anticipated for the sites of nuclear installations. From the tests an extremely durable battery cell has been identified which is little degraded by natural or accelerated aging and seismic stresses.

Improved Soniscope

With support from the CEA and Hydro-Quebec, Ontario Hydro is

developing a new Soniscope based on modern electronics technology for use in the non-destructive detection and location of cracks in hydro-electric dams and other mass-concrete structures. The original device was first developed by the Research Division in about 1949 and has since been in use commercially with little or no change in its design.

Failure Analysis

Conventional techniques for analysis of failure modes in power-system components are usually destructive as they require removal of representative samples for examination in the laboratory. Many components could be saved if there were effective techniques for in-situ, non-destructive metallurgical evaluation. Therefore a major effort was made with support from the CEA, to develop and refine such techniques.

Preparation of surfaces for microscopic examination has been made more efficient by improvements in abrasive and electrolytic polishing. Replication of surfaces also has an important role in metallurgical field work as the shape of components often makes in-situ microscopic examination impossible. Improvements in the convenience of replication and in its definition of metallurgical structure have been effected. These techniques have been used extensively in assessing the integrity of power plant components, such as the rotating parts of steam turbines.

New Applications of Holography

The aim of this work is to develop holographic procedures for in-situ analysis of flaws and vibration in tubes, piping and other station components. Holographic apparatus was used to observe vibration patterns in sections of pressure tubes and turbine blades. Images of standing waves were obtained, and in the case of pressure tubes, movement of garter springs to nodes was displayed. The work on turbine blades was done for a Canadian manufacturer and clearly showed blade vibration patterns as a function of excitation frequency.

This pressure switch is one of many devices tested for seismic qualification on the new small tri-axial shaker. The testing is part of an ongoing process to determine the ability of the many components of Hydro's nuclear stations to withstand seismic shock.





ransmission and distribution lines and transformer stations represent about one quarter of Ontario Hydro's capital investment. Facilities include about 27 000 circuit-km of transmission line and 100 000 km of distribution line, and associated transformer, switching and distribution stations.

Current transmission research programs are concerned with topics such as the uprating of existing lines and stations, while distribution research is focused on the development of techniques required for improved safety and reliability.

TRANSMISSION

Probability-Based Methods for Transmission-Line Design

In 1982, EPRI formed a team of experts, including personnel from Ontario Hydro, to prepare a comprehensive guide for use of probabilistic methods in the design of transmission lines. The deterministic design approach now in general use has limited ability to assess structural reliability in quantitative terms. The probability-based method, on the other hand, represents the variability of loads on structures and strengths of components more realistically and offers a quantitative measure of reliability level. Its adoption will enable utilities to reduce capital costs and maintain or improve reliability levels. EPRI expects to issue the guide towards the end of 1986.

The Research Division has made a significant contribution in the area of loads on conductors caused by ice and wind-on-ice. This section of the guide deals with definition of various ice accretions, use of models in calculating ice build-up, estimation of extreme ice accumulations and calculation of wind loads on ice-covered conductors.

Ontario Hydro has also provided detailed information on test sites used for monitoring wind and ice loads on transmission lines in Canada, the USA and Europe.

Optimization of Transmission Line Design

A program to optimize the design of transmission lines is under development. This treats conductors in an abstract way, because a standard conductor that meets optimum requirements for given load-growth profile and economic forecasts may not exist at present. The optimization process minimizes the sum of capital costs, and the present values of energy and peak power losses over the lifetime of the line. This results in an optimum



Towers lying like broken giants on the Essa to Claireville 500-kV transmission line are a result of a tornado that ripped through southern Ontario in the spring of 1985. Storms with such force are very infrequent and are not normally provided for in transmission-line design.

combination of conductor size, steel-to-aluminum ratio, bundle size, span length and type of support structure that meets given safety, reliability, environmental and political requirements.

Low-Loss ACSR Conductors

A model of ac resistance in steel-reinforced aluminum conductors (ACSR) recently developed by the Research Division is being used to design low-loss ACSR conductors. The ac loss of one conductor design has been reduced by

2.5% by a change in the lay-lengths of its three aluminum layers. This change is not expected to lead to a significant increase in the cost of producing the conductor. Other designs result in loss reductions of as much as 8%. However, these involve the use of different wire diameters in each aluminum layer which could increase costs.

Analysis and Improvement of the Thermal Environment of Power Cables

Several "user-friendly" desk-top-computer programs for thermal analysis of power cables have been developed and transferred to the R&D Division of CEA for distribution to all Canadian utilities and sale to American utilities and cable manufacturers. The programs will permit cable engineers to use desk-top computers in complete thermal analyses by either the classical Neher-McGrath/IEC method or modern finite element techniques.

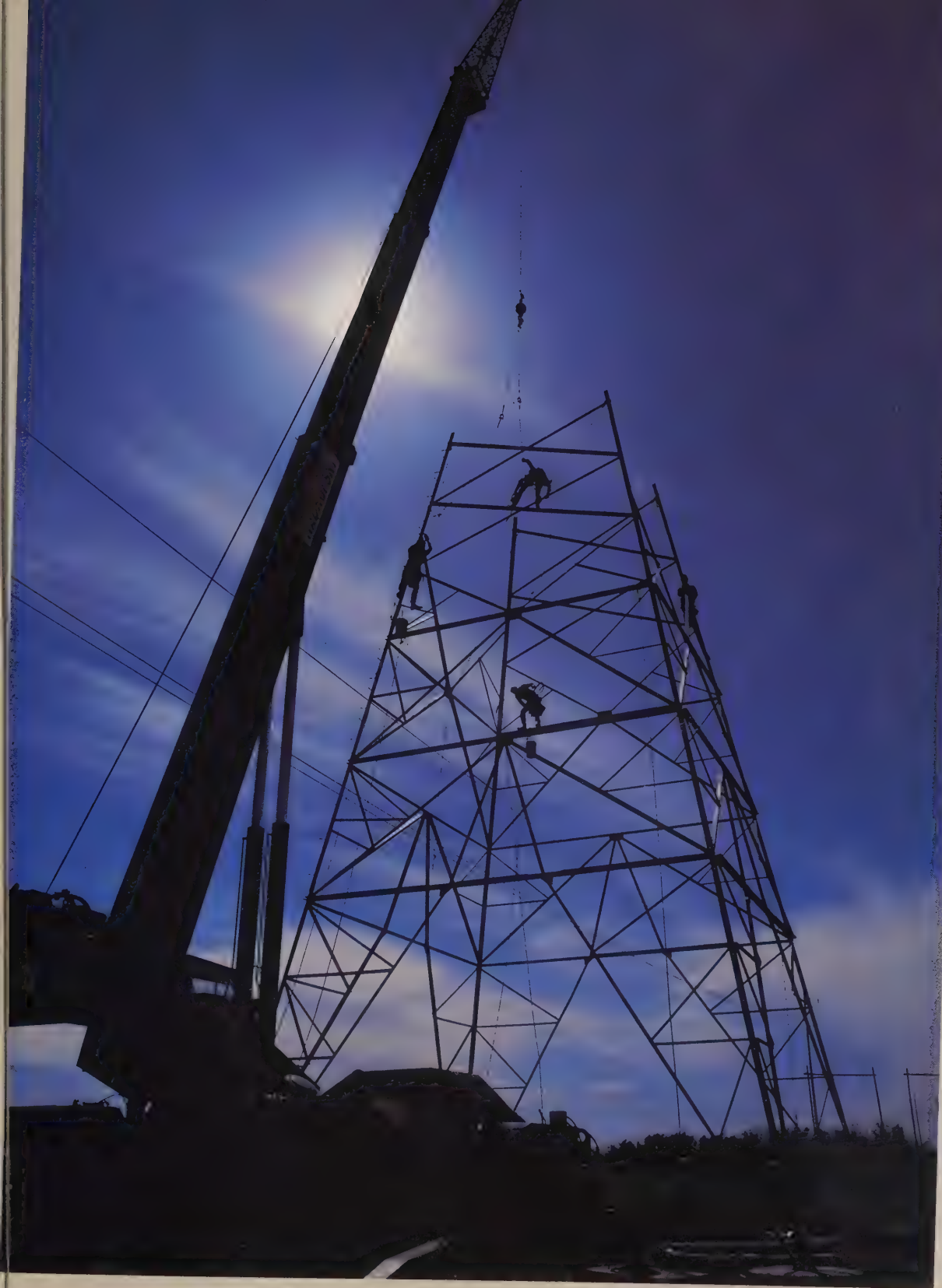
Re-radiation of Broadcast Signals by Transmission Lines

Guidelines that limit the effects of re-radiation by transmission structures on the broadcast patterns of nearby radio transmitters are an increasingly contentious issue in relations between electric power utilities and radio broadcasters. This trend is increasing demands by utilities for "user-friendly" computer programs developed by the Research Division which provide easy and accurate evaluation of the effects of proposed transmission lines on the broadcast patterns of nearby radio transmitters. The programs can also evaluate the effectiveness of various schemes to reduce re-radiation.

Power-System Harmonic Measurement

The power and telecommunication utilities are involved in a major effort to

Construction crews responded quickly after tornados destroyed transmission towers in southern Ontario. This photo, taken a week after the storm, shows a crew erecting a replacement tower with the aid of a mobile crane and fall protection equipment tested and evaluated in the Division's Mechanical Testing and Development Complex.



develop a comprehensive electrical coordination guide for utility engineers. As part of this, a Research Division project funded by the CEA is underway to develop a standard harmonic-measurement instrument that will provide convenient data for standards and procedures to improve control of power-system harmonic distribution. The project is scheduled for completion in 1986.

Metal-Oxide Surge Arresters for Transmission-System Protection

Metal-oxide arresters are becoming the dominant protective devices for major electrical equipment on transmission networks. However the electrical properties of the key protective components, the varistor elements, vary from one manufacturer to another. A number of studies have been undertaken by Research to support users in assessing and applying metal-oxide arresters. These include long-term thermal aging, x-raying of arresters to check internal structure, field testing, modelling, pulse testing, and development of arresters for application on underground cable systems. The Division is participating in the development of standards for metal-oxide surge arresters by committees of the CSA, the IEEE and the International Electrotechnical Commission.

Conductor-Vibration Control

Ontario Hydro and CEA-sponsored field trials of detuning pendulums and other devices for control of galloping on distribution lines and bundle-conductor transmission lines are now established at about 40 sites across Canada. Utilities are observing and filming conductor behaviour during ice storms.

The incorporation of detuning pendulums in the design of the Hanmer-Mississagi 230- and 500-kV lines is permitting upgrading of line reliability without redesign of structures or reduction of span lengths. Licenses for manufacture of devices applicable to single conductors have been granted to one Canadian and one Norwegian manufacturer.

Dampers for control of aeolian vibration of overhead transmission and distribution

lines from a number of sources in Canada and elsewhere are being evaluated on Ontario Hydro's indoor test-span. A new technique is being used which determines the energy absorption throughout the range of frequencies encountered during normal operation.

Spacer-dampers to control wake-induced vibration of four-conductor bundles are being evaluated in a field test on the Lennox-Newtonville 500-kV line. The vibration levels on each of the six phases, which are treated with different hardware, are being monitored by live-line recorders.

SF₆ Arcing Byproduct Analyzers

The Research Division has developed two low-cost analyzers of SF₆ arcing byproducts for use in gas-insulated substations. These are based on commonly available detector-tube technology and are very sensitive. They can be used by field staff without extensive training for rapid in-situ analyses, for diagnostic purposes and for fault location and partial-discharge detection. Testing of analyzers at substations after power arc faults provided excellent correlation with laboratory results.

In-Situ Testing of Soil

Devices for testing of soil in-situ along transmission-line routes offer considerable potential for reducing the time and labour involved with laboratory testing. Field tests which used a dilatometer, static cone, borehole shear device, Pencil probe, geophysical equipment, pressuremeters, and more conventional tools have been done at two soft-clay sites. Geotechnical Engineering is participating in the evaluation and is training staff to provide for future transmission line investigations on a production testing basis.

At the centre, a reinforcing cage is being lowered into an augered hole prior to the placing of concrete for a transmission-tower foundation in soft clay. The photograph also shows, at the right, the augering of another hole, and at the left, a finished foundation awaiting installation of equipment for an overturning-moment test.





The soft clay that underlies much of eastern Ontario loses strength when disturbed by construction and regains part of the loss by thixotropy over time. In cooperation with the National Research Council, drilled holes up to 3 m in diameter and 13 m deep are being load tested to determine parameters used for design of transmission tower foundations in this part of Ontario. Construction procedures are also being reviewed.

Anchor Grouting and Bearing-Pad Construction at Low Temperatures

In northern Ontario, transmission lines are often built in winter because the abundance of lakes, swamps and muskeg makes ground travel difficult in the warmer months. However, construction of small concrete footings and of anchors grouting in winter is expensive and time consuming. At present the rock surface is heated for up to 24 hours to provide a warm base for grouting the anchor bolts and mixing and placing conventional grout or concrete. The footing is then covered and heated for the three days needed for curing.

Research was therefore undertaken to

develop materials with properties that would mitigate these problems but still provide the necessary structural properties. The outcome was development of polymer materials which permit both anchor and base-plate grouting at temperatures as low as -25°C .

DISTRIBUTION

Distribution System Automation

The rapidly advancing technology of distribution-system automation involves load management, voltage control, remote switching, remote meter reading and other system-operation functions. Successful implementation of this technology requires an effective and economical technique for sending and receiving operational commands to and from remote devices.

Power-line carrier is an attractive medium for this purpose, but the technique must be made effective and reliable. A computer program, developed in a project sponsored jointly with CEA, can be used to analyze carrier-signal propagation and predict signal levels at any point on the distribution system. It will enable the

utility engineer to optimize parameters such as carrier frequency, required signal injection levels, and points of injection without need for costly field trials.

The feasibility of using commercially available fibre-optic equipment for distribution system communication is also being investigated in a project supported by CEA.

Improvements in Line Insulation

The transfer of insulator technology developed by the Research Division to local industry is leading to increasing use of lightweight, state-of-the-art polymer insulators for overhead distribution circuits. Approximately 35,000 polymer insulators are now installed yearly on Ontario Hydro distribution lines.

Ontario Hydro has played a major part in the development of the first industry guide for application of polymer insulators to overhead transmission and distribution circuits. This was published by the standards board of the IEEE in July 1985, as ANSI/IEEE Standard 987.

Research Division collaboration with

Readings are taken from the display of a pressure meter connected to probes installed at various depths in the soil to determine moduli of elasticity for use in the design of transmission-tower foundations.



the University of Windsor on polymer materials for electrical insulation applications outdoors has contributed to better understanding of insulator material performance and to development of improved materials. The program receives support from the National Sciences and Engineering Research Council, the Electrical Insulation Society, and industry.

Explosive Effects in Surge Arrester Failures

When a distribution surge arrester fails, the porcelain body sometimes bursts. A novel device for disconnecting the arrester ground-lead and eliminating this dangerous possibility has been developed in a program sponsored jointly by Ontario Hydro and the CEA.

The device can be attached to new arresters by the manufacturers and to existing arresters by the utilities. It works by rapidly cutting off the flow of fault current in a failed arrester in a way similar to the operation of a current-limiting fuse. However, the arrester, unlike the fuse, is not affected by lightning surges and normal power-follow currents. Negotiations are underway with a large surge arrester manufacturer for production of the device in Canada.

Strength Testing of Wood Poles

A test program of about five years duration has been initiated to establish a data base for the strengths of wood poles on Ontario Hydro distribution systems. An automated test facility has been designed, but at present only a temporary facility has been placed in service to permit testing for another utility of 34 poles which the company suspected of being under-strength. The results of these tests indicate that wood poles now going into service may be much weaker than had been expected. Further tests in cooperation with the other utility and their pole-treating company are planned.

The new facility, which is expected to be ready for use in the spring of 1986, will normally be capable of testing poles up to 26 metres long. Bending moments of up to about 1700 kN·m can be applied with the load rate and direction

automatically controlled to comply with the requirements of ASTM Specification D 1036.

Vegetation Control Along Overhead Lines

The periods of trimming cycles for trees under distribution lines depend on the rates and patterns of growth of various species and range from one to eight years. Extensions of some or all of these cycle times would substantially reduce tree-trimming costs. Experiments are continuing to determine the allelopathic effects of some cover crops and their potential usefulness in inhibiting the invasion of rights of way by undesirable woody species. The inhibition of seed germination by aqueous extracts prepared from these cover crops was found to be less than universal; one seed species is resistant and others may be. Extracts from older plants were found to be generally more inhibitory than those from younger plants. Improved knowledge of the competitive and allelopathic effects of some cover crops may lead to useful modification of the vegetation management program.

Determining Submarine Cable Ampacity

The increase in use of electric heating and the general growth of customer loads have increased the need for precise knowledge of the allowable ampacity of the submarine cables that are used to supply island customers on Ontario Hydro's rural distribution system. This cable is of unique and economical design; it has no concentric neutral and thus any return current flows via the ground, the water or the steel-wire armour that protects it.

At the places where the cables pass from water to soil and from soil to air (up a riser-pole) ampacity is of particular concern, for at these places there is an increase of current in the armour wires and a reduction of cooling. Tests have been made in the field to determine the amount of current typically flowing in the armour wires. In the laboratory, tests have been made to determine the temperature rises that occur in various sizes of submarine cables with various

currents flowing in the phase and armour wires. The results are being used to verify a computer program used to calculate cable ampacity. The work will allow loading of submarine cables to maximum capabilities with good assurance that they will not be overstressed and thus prone to failure.

Evaluation of Toxic-Gas Detectors

Portable detectors are used to test for the presence and concentration of toxic gases in confined spaces, such as manholes, where utility staff must often work. The Research Division has evaluated nineteen detectors from a number of manufacturers in a program supported by Ontario Hydro, the Association of Municipal Electrical Utilities (Ontario) and the CEA. The program has established the effects of instrument-related factors (design, calibration, operating instructions, servicing and handling) and of workplace conditions (temperature, humidity and interfering gases) on the reliability of measurements provided by the instruments in various applications. This information will be useful in choosing the most suitable instrument for a specific application.

Distribution Instrumentation

A microprocessor-based Maximum Demand Indicator, developed for use in revenue-metering applications, accepts pulses from kW·h and kVA·h meters, and displays the maximum kW and kVA demands and the present power factor. The federal government has approved use of the demand indicator in billing applications and a licence has been awarded to an Ontario company to produce the device and sell it to other utilities.

The Ampere-Cycle Totalizer, recently developed by the Research Division, provides information for use in decisions on the timing of breaker maintenance. It monitors the magnitude and duration of the arcing current to which breaker contacts are subjected, and stores and displays a cumulative total of these ampere-cycles for the life of the breaker. The peak fault current interrupted by the breaker is also measured and stored.



Because of its high efficiency and relatively low cost, electricity is an attractive alternative to oil and gas as an energy source for many industrial applications. It can also provide other benefits, such as reduced waste, clean working environments and improved productivity and quality control.

INDUSTRIAL

In a continuing search for novel and advantageous applications of electricity in industry, the Research Division investigates new electrotechnologies as they develop. Those of special interest at present include applications of heat pumps, plasma arcs, radiant energy and electromagnetic devices, and new processes in the electrochemical and ceramics industries.

Radiant-Energy Technologies

Radiant energy technologies include applications of microwave, infrared, ultraviolet, laser and electron beam

devices. These electrically based technologies offer significant benefits to industrial users through increased productivity, improved product quality and more efficient use of energy and space.

Two versatile test facilities which demonstrate the application of microwave and infrared technologies in various manufacturing processes were commissioned. Preliminary assessments have been made of the benefits of microwave heating in terms of increased product throughput and reduced energy consumption. For example, assistance was given to a manufacture of rubber products. Laboratory tests demonstrated that the heating of rubber using microwave radiation was more energy efficient than by using conventional sources.

Applications of microwave, radio-frequency and infrared devices in manufacturing were investigated jointly by CEA and Ontario Hydro. This study, which is of special interest to utilities, examines the application of these

electroheat devices worldwide and indicates possible opportunities for their use in Canada.

Heat-Pump Drying

The heat pump is a machine that can produce low-cost process heat by recovering and upgrading heat previously lost during manufacturing processes. Thus, this technology can be used to dry products using a fraction of the energy required otherwise. For example, heat-pump dehumidification is currently being used to dry hardwoods for the manufacture of furniture. The use of heat-pump dehumidification to lower the cost of producing other wood products, thread, food and textiles is also being explored. Preliminary investigation, made in cooperation with a thread manufacturer, has shown that conversion of the drying process from resistance heating to heat-pump dehumidification can result in a 50 per cent reduction of the electrical energy used. Through studies like this, conducted in cooperation with manufacturers and equipment suppliers, Ontario Hydro can help Ontario industry benefit from the use of this efficient electrotechnology.

Electrochemical Technologies

A study, jointly funded by CEA and Ontario Hydro, of the impact of new electrochemical technologies and processes on the demand for electrical energy was completed. Some of the areas showing possible commercial opportunities included primary metal recovery, inorganic chemical production, pollution control and electro-organic synthesis. The roles of industry, educational institutions, government and electrical utilities in promoting this opportunity in Canada were defined.

In some industrial processes, membrane separation technology is used to separate one substance from another. In this technology thin films of certain organic polymers form barriers that permit molecules of one kind to pass but exclude all others. A report was issued which reviewed the current applications of membrane processes. These offer the potential of both saving energy and improving productivity, as compared to

The use of microwave technology can dramatically enhance industrial productivity through increased production rates, higher yields and improved product quality. Applications of microwave heating range from the preheating of rubber to drying of ceramic products. A test on a wood product is shown.





Wood is one of many products being tested in a heat pump dehumidification kiln as part of a program to demonstrate this efficient drying method. Textiles, grains, malts and fruit are some of the other products being considered for the heat-pump dehumidification process.

conventional techniques such as evaporation or distillation. Intended as a primer for utility personnel, the report summarizes the application opportunities and development needs in this relatively new technology.

Electromagnetics

Research is being conducted to harness electromagnetic fields to produce large forces and high temperatures in a well controlled manner. The Electromagnetics Laboratory was substantially upgraded during the year to facilitate both research work and the demonstration of this advanced technology to Ontario industry.

Problems in the application of induction heating for heat treating and metal processing were investigated. Technical assistance was provided to several manufacturers on development of improved methods for annealing of special cables, hardening of automotive parts and melting of disposable metal beverage cans.

Thermal Plasma Technology

The Thermal Plasma Laboratory, which features an 80-kW plasma torch equipped with a powder injection system, has been utilized in several research programs. These have included studies of the processing of ceramic powders, metallurgical processing of compounds to produce ceramic magnets, recovery of magnesium and fluorine from uranium oxide process waste-streams, and the production of metallurgical reducing gases from coal-steam mixtures. All of these programs were conducted in collaboration with external agencies. A second plasma laboratory under construction adjacent to Lakeview TGS will use a 250-kW plasma torch in a

as resistance to corrosion. High-temperature strength and wear resistance are other attractive features. The Research Division has taken steps to help industry develop efficient processes for the production of ceramic materials and components. Much of the present interest in these materials is related to their possible use in diesel and gasoline engines.

The Thermal Plasma Laboratory and the Microwave Facility have been used in several ceramic material processing projects with Ontario manufacturers. An induction plasma system is being added to expand the capabilities of the plasma laboratory.

RESIDENTIAL

Interest in comfort and safety and efficient energy use in the home has grown considerably in recent years. The Division's efforts have been directed at efficient energy management and have included development of a cold-climate

Advanced Ceramics

Advanced ceramics are characterized by superior strength and hardness and have desirable chemical properties such

heat pump, and studies of the thermal upgrading of homes and the recovery of waste heat.

Cold-Climate Heat Pumps

Laboratory testing of a new air-source heat pump has shown that its low-temperature efficiency is the best in the world. This residential heat pump, with improved performance in Canadian climatic conditions, was developed by the Research Division in a project supported by CEA.

Following release of the Research Division's design report to the heating, ventilating and air-conditioning industry, CEA authorized a Canadian manufacturer to develop a commercial design and build seven prototypes units. These were shipped to utilities in both Canada and the U.S.A. for field testing. Successful performance of the electronically controlled expansion valve and other features could influence the design of future generations of heat pumps and result in energy savings worth \$18 M in Ontario over the next ten years.

Thermal Upgrading of Houses

Sixteen houses equipped with dual-energy heating systems were thermally upgraded and their energy consumption monitored for a year before

and a year after the retrofit to determine any changes in energy consumption and demand. On average, energy savings amounted to six per cent while peak power demand was reduced by thirteen per cent. Although the saving to customers was much smaller than predicted, thermal upgrading of homes is still a strategic conservation measure.

Patterns of Hot-Water Use

Domestic water heating represents a major use of energy in the average home. Over the past decade, the structure and life-style of the family have gone through changes that have altered the household's hot-water consumption.

Data compiled over the past four years from fifty-eight homes show that knowledge of the total daily and peak hourly hot water use is important in the accurate sizing of water-heating systems. New design and evaluation criteria based on the hot-water consumption patterns observed in this study will be of assistance in the design of water heating systems.

Conservation

Research activities were directed towards the testing and evaluation of a new generation of heat-pump-based devices that provide mechanical ventilation and

humidity control to improve indoor air quality. The devices recover a large part of the thermal energy in the exhaust air for use in space and water heating.

Waste-water heat recovery systems were also assessed. These systems are designed to transfer heat from warm residential waste water, such as that from clothes washing, dishwashing and showers, to fresh, potable water, which can be stored in a domestic hot water storage tank.

The attractiveness of these relatively new technologies stems from their high efficiencies. Consequently there is the potential for significantly lowering energy consumption in both new and retrofit applications.

Residential Service Entrance and Wiring

As part of its mandate, the Research Division has looked at ways to improve the performance and reliability of customer-owned electrical equipment.

A prototype "smart" fuse has been designed that will allow the homeowner to add the comfort of supplementary baseboard heating to any room in the house by merely plugging the heaters into existing wall receptacles. Any overload on the circuit is detected by an electronic mini-breaker device that replaces the standard fuse in the panelboard. It then transmits a signal to turn off or reduce the output of the baseboard heater to remove the overload condition. Once the device responsible for the overload is removed from the heater's circuit, the heater is allowed to resume normal operation. When fully developed, the "smart" fuse will be ideally suited for the retrofit market.

A study was conducted for CEA to develop methods of minimizing fires arising from residential service entrance panelboard failures. After testing of ceramic fibreboards and various types of sprays, foams and pastes applied to panelboards, a recommendation was made that a minimum standard for panelboard backing materials should be incorporated into regulatory standards.

Successful research and development requires the transfer of ideas from the laboratory to the marketplace. Shown here with prototype units of the CEA northern climate heat pump that are now undergoing field trials in Canada and the United States are representatives of the three key organizations that took this development from conception to reality. From left to right are: Dave Robertson and Grant Blackmore, from KeepRite Inc; Fred Kee and Ed Ezer, Directors of Research from Ontario Hydro and CEA respectively; and Dave Young and Anton Baljet, from Ontario Hydro's Electrical Research Department.



Tests to determine the merits of the tin-plating of fuse contact surfaces indicate a three-to-one reliability improvement for heavily loaded fuses that are tin-plated. The tin plate was found to give a better connection and to reduce the incidence of nuisance fuse-blowing.

Heating-Load Calculations

Calculations of residential heating loads using measurements from previous dual-energy and thermal envelope upgrading experiments indicate that, in general, furnaces have roughly twice the capacity needed. This results in increased capital cost and a lower comfort level for the homeowner. A significant contribution was made to a new CSA standard to be used for sizing furnaces supplied by any type of energy.

COMMERCIAL

Throughout the year, various ways of improving the efficiency of energy use in commercial establishments were investigated. Research was carried out in such diverse areas as the use of warm water discharged from generating stations for freshwater-prawn farming and the suitability of heat-pump water heaters for commercial applications.

Thermal Aquaculture

Work continues on determining the feasibility of growing Malaysian prawns in warm-water discharges from stations. The investigation, which initially centred on the selection of the optimum diet for the prawns, is now at the stage where the amount of food required for optimum growth of the animals is being studied. A preliminary "growout" trial of these animals to marketable size produced yields comparable to those reported for commercial Hawaiian ponds.

Commercial Heat-Pump Water Heaters

With increasing energy costs and general public awareness of the benefits of energy conservation, heat-pump water heaters have emerged as an attractive option for increasing the efficiency of electric water heating in commercial

applications. Over 10 MW·h were saved during the year in a restaurant where a small heat-pump unit was installed to air condition the kitchen and to heat water for various applications.

Within the framework of a CEA project,

a larger heat-pump water heater has been recently installed in this restaurant. This example may encourage other commercial hot-water users such as hotels, laundries, apartment buildings and public swimming pools to take advantage of the benefits offered by heat-pump water heaters.

Several prawn aquaculture studies that would make practical use of low-grade waste heat from nuclear stations were conducted throughout the year. Tests were conducted to determine the minimum daily food ration for optimum growth of the prawns.



Environmental Protection



he Research Division undertakes studies of the effects of power-system operation on the biosphere to support the Corporation in

following guidelines and regulations set by environmental assessment and control agencies. Procedures, processes and equipment are developed as necessary for the control of emissions and effluents from generating stations and related installations, and for the safe handling, storage and disposal of waste materials. Other areas of study include diversion of fish from station water intakes and conversion of toxic substances to harmless products.

POLLUTION-RELATED STUDIES

Limestone Injection for Combustion-Gas Cleaning

A limestone injection system now under development for possible application to Ontario Hydro's coal-fired generating units could reduce sulphur-dioxide emissions by as much as 50 per cent. A prototype system has been installed at one of the 300-MW units at Lakeview TGS.

A research program in support of the project is providing information necessary to evaluate the applicability of the limestone-injection technology to Ontario Hydro units and to enhance the technology available for the clean use of coal. The program will both contribute to and supplement the full-scale prototype tests at Lakeview TGS. The program objectives are: to determine the operating conditions required to achieve optimum SO₂ capture and sorbent utilization; to evaluate the performance of electrostatic precipitators under optimum process conditions and to develop methods to improve their performance; and to assess the slagging and fouling potential in the furnace from increased ash loading.

The operation and performance of nineteen portable, direct-reading gas monitors were evaluated in a project co-funded by CEA, the AMEU and Ontario Hydro. These monitors are used to test the atmosphere of confined spaces both prior to entry of personnel and while work is in progress.





In the first phase of the program, thermogravimetric analysis was used to study the reactivity of six Ontario limestones and one limestone was recommended for pilot-plant tests. A bench-scale reactor which will allow more precise studies of the calcination and sulphation reactions of various adsorbents under controlled conditions has been designed and built. Models developed by the US Environmental Protection Agency and others have been evaluated and a suitable one has been obtained to study expected limestone behaviour in boilers.

The second part of the program is being conducted at Ontario Hydro's 640-MJ/h Combustion Research Facility. To meet the requirements of the program, the Facility has been upgraded to include a furnace quenching system, limestone and water injection systems, an isokinetic sampling system, and a coal grinding and pneumatic conveying system.

Modelling of Cloud Chemistry

In cloud-chemistry studies co-funded by CEA, schematic models were developed to examine the role played by stratus, cumulus and frontal clouds in redistribution of air pollutants and formation of atmospheric acids. Work on dynamic models with increased credibility is well underway.

Acid-Rain Studies

In a project co-funded by CEA, the first extensive field measurements of dry deposition - the direct deposition of sulphur and nitrogen oxides and other air pollutants directly on the earth's surface - were made in the vicinity of Bradford, Ontario. The results are being analyzed.

The Research Division's version of Fisher's Model was further improved and used to calculate Ontario Hydro's contribution to acidic deposition. This information is required by the Technical and Training Services Division.

Equipment and procedures acquired or developed over the past few years for measuring air quality around Lakeview TGS were transferred to the Technical

and Training Services Division, which now performs this function.

Atmospheric Dispersion at Nuclear Station Sites

Techniques developed for studies of atmospheric dispersion at the sites of nuclear generating stations were applied at Darlington NGS, where SF_6 was released and its concentration monitored downwind by an array of samplers. A one-year dispersion climatology study of the Bruce area was also completed. Ontario Hydro's needs for mesoscale meteorological data were assessed, models for deriving such information were evaluated and a course of action was proposed.

Two dispersion models, one for puff releases and the other for continuous releases, were included in microcomputer programs for use in setting up the Pickering '85 nuclear contingency exercise. Versions of the model were transferred to Ontario Hydro and government representatives in the Provincial Nuclear Emergency Task Force for their use during the exercise and in other applications.

Improvement of Doppler SODAR

Sound Detecting And Ranging (SODAR) equipment based on the Doppler effect was upgraded through the acquisition and installation of transceiver and telemetering components of increased sensitivity, and the capabilities of the improved system were demonstrated. SODAR is expected to become the accepted technique for collecting upper-air meteorological data within Ontario Hydro.

Biological Conversion of Radionuclides

In support of the Canadian Fusion Fuels Technology Project, studies were continued of the biological behaviour of tritium released from nuclear generating facilities to the terrestrial and aquatic environments. Investigation of elemental tritium - a form expected to be emitted in minute quantities from the Tritium Removal Facility at Darlington NGS - showed that soil and leaf litter are the dominant sites in the terrestrial environment for microbial conversion of elemental tritium to tritiated water, the more radiotoxic of the two. Further investigation of the uptake and desorption of tritiated

A Lyman-Alpha hygrometer is being installed on a tower to determine the dry deposition rates of acid gases in an acid rain research program.



water in various aquatic and terrestrial species is expected to show little or no retention of tritium in the receptor organisms.

In related laboratory studies, the distribution of gamma radionuclides of cesium and cobalt in bottom sediments from the western basin of Lake Ontario is being determined.

The conversion of elemental hydrogen, deuterium and tritium to oxide forms is

catalyzed by certain bacterial strains which can produce the enzyme, hydrogenase. Three of these strains were selected for laboratory evaluations of their potential for producing the enzyme under a range of growth conditions. Two of the strains produced high levels of hydrogenase when grown on a variety of organic substrates and are therefore suitable for mass cultivation on an economic scale. Elemental tritium, present as a contaminant in an atmosphere containing normal concentrations of

hydrogen, was rapidly oxidized to tritiated water (HTO) by both bacterial strains. The optimization of culture conditions to maximize growth and hydrogenase activity is continuing. Several applications are possible for hydrogenase catalysis within the areas of fusion and fission technology.

Carbon-14 Studies

A laser-based process for enrichment of the carbon-14 ratios in ground water has been demonstrated in the laboratory, as part of work being performed in support of AECL's nuclear waste disposal program. The process will facilitate the radiocarbon dating of older ground water, which provides important information required in the selection of sites for nuclear waste repositories.

Assembly of a prototype cryogenic still for use in removing and concentrating the carbon-14 present in moderator cover gases and ion-exchange resins was completed and commissioning was begun.

Environmental Surveys at Generating Stations

Surveys were continued in the pre- and post-operational phases at Darlington NGS, Pickering NGS 'B', Bruce NGS 'B' and Atikokan TGS to assess the impact of the stations on the environment. Other studies of the distribution of fish schools and spawning of whitefish are in progress at the Bruce 'B' and Pickering generating stations.

WASTE MANAGEMENT

Concrete Cask for Irradiated Fuel

An integrated concrete cask is under development for the interim storage and transportation of irradiated nuclear fuel. Two half-scale models of the cask were constructed and tested. One underwent two drop tests and exposure to fire at 1000°C. The second was subjected to heat loads that simulated the decay heat of irradiated fuel internally and various ambient temperatures externally. Each model retained its structural integrity in

Early in the spring, researchers began a study to determine the effects of growth regulators injected into the trunks of 12-year-old silver maple trees on the growth of sprouts. This work is part of a program to control tree growth under transmission and distribution lines.



all tests. The design is expected to provide full containment of the irradiated load in the event of a transportation accident.

Permeability of Gasket for Irradiated-Fuel Cask

Krypton-85 and iodine-131 are two of the radionuclides that will be present in a stainless-steel irradiated-fuel cask being designed by Ontario Hydro. Both could permeate the cask gasket and pass to the environment. Because information on the permeability of the proposed gasket material is limited, permeation by the two species was determined at 60°C to 200°C in a gas chromatograph. They were found to be similar in behavior to the reference gas, helium.

Copper Containers for Nuclear Waste

Evaluation of copper as a container material for use in the disposal of irradiated nuclear fuel in hard-rock repositories is continuing. In tests thus far, copper has shown adequate integrity and durability as a barrier to the migration of radionuclides to the biosphere, and high resistance to corrosion in the most probable repository environment. Under worst-case conditions involving radiolysis and sulphide attack, however, corrosion rates increase and some pitting occurs. The project will provide corrosion data to AECL for use in overall appraisal of concepts for permanent disposal of high-level wastes.

Conditioning of Tritiated Aqueous Waste

When in operation the Tritium Removal Facility at Darlington NGS will generate quantities of tritiated aqueous waste that will require solidification and suitable packaging for its disposal. The waste package is the major barrier to tritium releases to the environment which must be less than 10^{-3} per cent of the original activity per day. The effects of the solidification medium and the container material and dimensions on the amounts of tritium release have been quantified as a basis for design of the package.

Solidification of Radioactive Aqueous Waste

Prototype equipment for the solidification of irradiated aqueous waste with a water-extensible polymer has been constructed and demonstrated. The equipment is compact and portable and can be operated either manually or automatically at a throughput of five litres per minute. Production models could be shipped to stations as needed rather than having a unit on hand at each station.

Characterization of Reactor Waste

In support of the development of facilities for the disposal of low- and intermediate-level wastes, the composition, activity level and radionuclide inventory of compactable reactor waste has been determined, and characterization of incinerable, non-processable and retubing wastes is continuing. This information will be essential for environmental assessment and licensing of future disposal facilities.

In-Ground Disposal of Low- and Intermediate-Level Wastes

Of various materials evaluated for use as backfill in the glacial till at the Bruce in-ground waste-management facility, a fluidized cementitious grout exhibited low viscosity, minimal phase-separation and shrinkage, uniform density after hardening, and adequate durability and strength. The grout fills voids and, when set, provides mechanical support for the waste packages. Studies are continuing of the effectiveness of the grout in controlling the release of carbon-14 and other radionuclides.

Sorption of Radionuclides by Normal and High-Density Concretes

Investigation of the permeability and radionuclide sorption of several types of normal and high-density concretes in cooperation with a West German research centre showed that the extent of microfracturing determines the permeability of concrete containers for storage of nuclear wastes. Sorption levels of plutonium and americium radionuclides

varied considerably with the type of concrete, but were generally lower than desired. Future work will examine the use of geochemically active additives and aggregates to increase the sorption capacity of concretes designed for nuclear use.

Outdoor Storage of Irradiated Fuel Channels

A high-density concrete was recommended for the fabrication of modules for outdoor storage of irradiated reactor-fuel-channel assemblies removed from Units 1 and 2 of Pickering NGS 'A' under the large-scale fuel-channel replacement program. Because the structural use of high-density concrete as radiation shielding has been limited to indoor applications, little information was available on its performance outdoors. After laboratory testing and full-scale field trials, final adjustments were made to the mix design and placement procedures to assure proper quality of the end product.

Stresses in Ontario Rock Formations

In a project initiated by AECB and undertaken by Ontario Hydro, drilling and overcoring tests were made to investigate the magnitude and orientation of in-situ stresses and to assess seismotectonic conditions in sedimentary and crystalline rock formations. The data will help establish the risk of damage from seismic activity in eastern Canada.

A computerized borehole dilatometer was developed as an improved geological aid for evaluation of deep rock masses as potential sites for disposal of low- to high-level nuclear wastes. The ability of the dilatometer to operate at depth in small-diameter boreholes provides an economical means of determining deformation moduli, in-situ stresses and location of fractures in preliminary studies of a rock mass.

Thermal Modelling of Nuclear Waste Disposal Vaults

Experimental modelling of heat and

moisture diffusion around a theoretical, backfilled, high-level nuclear disposal vault was undertaken to predict temperature and groundwater regimes in the post-closure period of the vault. The behaviour of a clay-based buffer and a bentonite and sand backfill mixture will be evaluated under various simulated heat and groundwater flow conditions. Experience with the instrumentation, the design of experiments and the predictive procedure will be transferred to AECL for use in tests planned for their Underground Research Laboratory at Pinawa, Manitoba.

Geological and Geochemical Conditions of Oklo Natural Reactors

Information on the geological and geochemical conditions of the Oklo natural reactors in Gabon, Africa, has been gathered and evaluated for AECB in cooperation with the University of Western Ontario. The Oklo case can be applied as a natural analog for assessment of the validity of long-term conclusions reached concerning underground repositories for nuclear waste. The information has been useful in defining the optimum geochemical conditions for a waste repository and the limitations imposed by temperature, radiation, radiolysis and other influences.

Management of Waste from Limestone-Injection Process

In the limestone-injection process now under development for control of emissions from coal-fired stations, powdered limestone reacts with sulphur dioxide to form calcium sulphate, which is collected with the coal ash for disposal. In the development of procedures for management of limestone-injection waste, the chemical composition, reactivity and leaching properties of waste from a plant in Virginia and from preliminary trials at Lakeview TGS were determined. Treatment of the waste materials by the addition of water or ordinary fly ash to improve their leach resistance and physical strength was tested. Safe handling methods and environmentally sound options were developed and recommended for disposal of the waste.

Monitoring of Coal-Ash Disposal Sites

Monitoring in the vicinity of coal-ash disposal sites at the Domtar and Booth quarries and at Thunder Bay TGS and Atikokan TGS was continued through the year to ascertain the impact of ash placement on the quality of surrounding ground and surface waters. No adverse effects from leachates originating from the sites have been observed to date.

Removal of PCBs from Insulating Oils

Performance testing of a 6000-litre-per-day trailer-mounted dechlorination facility for the removal of low levels of polychlorinated biphenyls (PCBs) from insulating oils neared completion and final government approval of the equipment and process was awaited. Treated oil from the dechlorination process is suitable for re-use in transformers and capacitors. Treatment provides a preferred alternative to long-term storage of contaminated oils. A non-exclusive licensing agreement was signed with a Canadian company for rights to use the process in Canada. An agreement is being negotiated with a second company for rights to the US market.

Reclamation of Downgraded Heavy Water

Laboratory investigation showed that use of a fixed carbon bed would be effective in the reclamation of heavy water from 41 000 kg of downgraded stock containing a persistent oil emulsion that could not be removed by the existing clean-up train at Pickering NGS. The process should yield for re-use about 5000 kg of nuclear-grade heavy water valued at \$2 million.

AQUATIC STUDIES

Repulsion of Fish from Station Water Intakes

Work continued on several systems for the guidance and repulsion of fish which at times clog the water intakes of generating stations. By altering fish behavioural patterns, some of these systems also have potential for use in commercial fisheries operations.

A Hidrostral fish pump and transport system was effective in passing, unharmed, pelagic fish species in the forebay at Pickering NGS and American eels at Saunders GS. The effectiveness of air bubbles as an alewife excluder was improved with the addition of strobe lights.

Pneumatic poppers, a sonic deterrent, effectively repelled alewife from the fish diversion structure at Pickering NGS. In work funded by the Empire State Electric Energy Research Corporation two mechanical sonic devices — a fish drone and a fish pulser were developed. These devices are more reliable than pneumatic poppers and have superior acoustical characteristics. During preliminary tests at Lennox TGS and Pickering NGS, both devices showed promise for excluding pelagic species from the intakes of generating stations.

A sonar-based system has been assembled that automatically activates deterrent devices as fish densities increase. Field trials of the system, which comprises mainly an acoustic transceiver and signal switching and integrating components, have begun.

A Model Benthic Sled

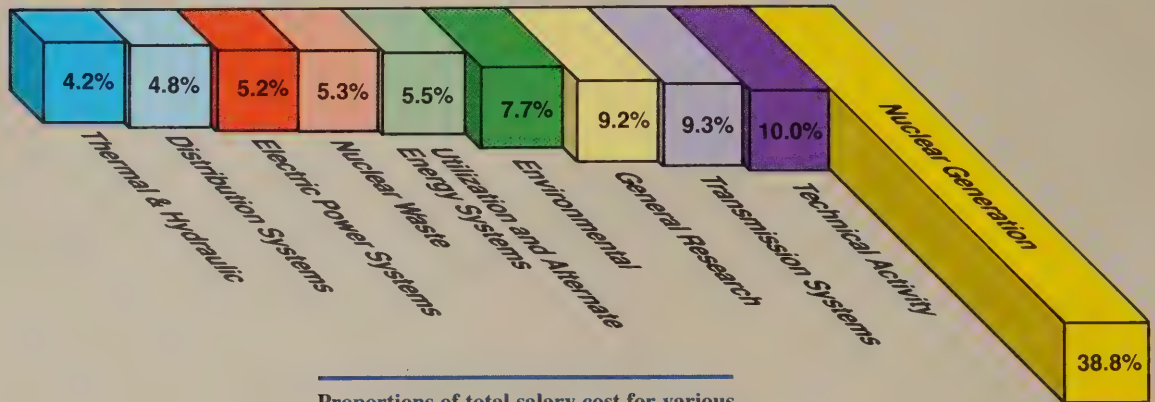
Periodic counts of benthic fish larvae can provide a good measure of the effects of generating-station operation on bottom-dwelling species. The effectiveness of a laboratory-scale benthic sled for the capture of round whitefish larvae was tested in a 15-m-long flume. The sled was effective in capturing larvae on a smooth, concrete bottom, but much less so on a more typical irregular, fine-cobble bottom. Success was better under twilight conditions when larvae commonly rise several centimetres off the lake bottom, and this suggests that night operations may improve the likelihood of capture. It was noted also that most larvae in the flume become detached in currents greater than 10 cm/s, resulting in a large catch. This suggests that drift nets placed on the bottom would likely be effective in capturing whitefish larvae displaced by lake currents.

Resources and Costs

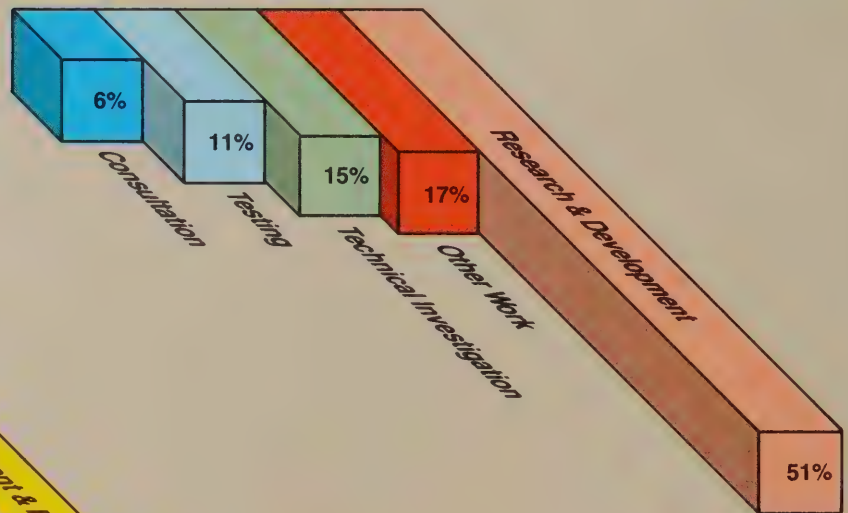
At the end of 1985, the Division's personnel resources consisted of a total regular staff of 621. The administration and organization of staff are shown on the opposite page.

The distribution of staff in broad occupational classes and its application in various categories of work (Divisional Services Department excepted) are shown below.

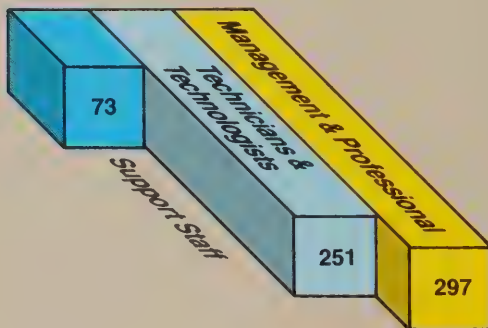
Research Division Programs for 1985 - Proportions by actual gross cost



Proportions of total salary cost for various categories of work



Occupational classification of Research Division staff



The total of all costs, including those for space, material and equipment for work done by the Research Division in 1985 was approximately \$50.1 M.

Costs were met or allocated as follows:

Revenue from work done for other organizations	4.0M
Transfers to other Ontario Hydro Branches	22.6M
Transfers to the Cost of Power	23.5M

Organization

DIRECTOR OF RESEARCH F.J. (Fred) Kee

CHEMICAL O.A. (Al) Kupcis

ANALYTIC
SERVICES
M.R. (Mike) Booth

BIOLOGICAL
RESEARCH
G.L. (John) Vascotto

ENVIRONMENTAL
& INORGANIC
D.J. (Dave) Dodd
ATMOSPHERIC
O.T. (Octavio) Melo

ORGANIC
R.W. (Roger) Glass

DIVISIONAL SERVICES J.B. (Bruce) Brown

BUSINESS
ADMINISTRATION
G.E. (Jerry) Craig

INFORMATION
MANAGEMENT
C. (Celina) Moraes

DRAFTING
W.S. (Bill) Davies

MODEL SHOP
W.S. (Bill) Davies

EDITORIAL
R.A. (Bob) Johnson

CIVIL T.W. (Tony) Klym

CONCRETE
CONTROL
G.M. (Gord) Kidd

CONCRETE
TECHNOLOGY
G.S. (Paul) Kella

ROCK SCIENCES
A.T. (Alex) Jakubick

SOILS
T.J. (Tom) Carmichael

DIVISIONAL PROJECTS J.G. (Jack) Cassan

RESEARCH
PROGRAM
(Vacant)

SPECIAL STUDIES
C.J. (Craig) Simpson

MECHANICAL G.J. (Gord) Clarke

APPLIED
STRUCTURAL &
SOLID MECHANICS
J.A. (Jim) Chadha

MECHANICAL
TESTING &
DEVELOPMENT
D.B. (Dave) Craig

NUCLEAR PROCESS
COMPONENTS
TEST FACILITY
R.T. (Ron) Hartien

PLANT EQUIPMENT
DYNAMICS
T. (Ted) Loewen

ELECTRICAL A.F. (Anton) Baljet

UTILIZATION
J.M. (Mike) Bell

SCIENCE
N. (Mikk) Anyas-Weiss

STATIONS &
UNDERGROUND
G.L. (Gary) Ford

SYSTEM
STUDIES
D.C. (Dave) Lee

TRANSMISSION &
SPECIAL PROJECTS
O. (Olaf) Nigol

ELECTRONICS &
INSTRUMENTATION
R.D. (Doug) Brown

ELECTRICAL
TESTING
& DEVELOPMENT
J.N. (Jack) Edgar

METALLURGICAL J. (Jim) Brown

NONDESTRUCTIVE
& FRACTURE
EVALUATION
J.A. (John) Baron

CORROSION
& TRITIUM
TECHNOLOGY
P.C. Lichtenberger

MATERIALS
INTEGRITY
PROJECT
R.G. (Ron) Fleck

METALLURGY
W.H. (Scott) Lawson

OPERATIONS RESEARCH J.G. (Jack) Cassan [Acting]

OPERATIONS
RESEARCH
A.H. (Archie) Chung

RELIABILITY &
& STATISTICS
J. (John) Endrenyi

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GENERATION

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Deans, J.J.

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*with an organization other than Ontario Hydro

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Barrett, J.S., Nigol, O., Fehervari, C.J.*, and Findlay, R.D.*

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"Reliability Assessment in Power System Operation", Royal Institute of Technology, September 18, 1985, Stockholm, Sweden.

"Reliability Studies in Electric Power Systems - An Overview", Electric Power Research Institute of China, June 25, 1985, Beijing, People's Republic of China.

Fujimoto, N.

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Bell, J.M.

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Haymes, G.T., and Patrick, P.H.

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***with an organization other than Ontario Hydro**

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Cervoni, A.

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"The Use of Interruption Costs at Ontario Hydro", IEEE Industry Applications Society, October 7, 1985, Toronto, Ontario.

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Harvey, S.M.

"Control Wiring Transients and Electromagnetic Compatibility in GIS", International Symposium on Gas-Insulated Substations, 1985, Toronto, Ontario.

"The Hazards of Studying VDU's", Seminar at McMaster University, September 11, 1985, Hamilton, Ontario.

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Kee, F.J.

"Address to AMEU Summer Conference for Management", June 4, 1985, London, Ontario.

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*with an organization other than Ontario Hydro

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Thomas, G.F.

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Abbreviations and Acronyms

AECB	Atomic Energy Control Board (of Canada).
AECL	Atomic Energy of Canada Limited - the crown corporation that developed the CANDU system
AERE	Atomic Energy Research Establishment (of the United Kingdom Atomic Energy Agency).
AMEU	Association of Municipal Electrical Utilities - the utilities to which Ontario Hydro supplies power
ANSI	American National Standards Institute.
ASTM	American Society for Testing and Materials.
CANDECOM	A process developed by Ontario Hydro and AECL which uses a dilute, regenerable solution to decontaminate the interior surfaces of nuclear reactor systems.
CANDU	Canada Deuterium Uranium - a nuclear reactor that uses deuterium oxide (heavy water) as moderator and as heat-transport medium and natural (unenriched) uranium as fuel.
CEA	Canadian Electrical Association - an association of electrical utilities that is dedicated to the development of policies and programs for the production and distribution of energy with an optional combination of environmental effects and user benefits.

COG	CANDU OWNERS GROUP - AECL and Ontario Hydro and other electrical utilities with interests in the development and operation of CANDU units.
EPRI	Electric Power Research Institute - a national organization for research and development supported by electrical utilities in the United States.
GS	Generating Station - The term without a descriptive prefix is used for hydro-electric stations on the Ontario Hydro System. The oldest has been in operation since 1898.
IEEE	Institute of Electrical and Electronics Engineers
IREQ	Institut de Recherche d'Hydro-Québec (Research Institute of Hydro-Québec).
NGS	Nuclear Generating Station.
TGS	Thermal Generating Station (fossil-fired)



SIGNIFICANT RESEARCH CONTRIBUTION

This programmable controller, designated the OH-180, is one of several microprocessor-based devices designed and developed by the Research Division and manufactured by Canadian industry in the quantities required by Ontario Hydro for use on the power system. In Darlington NGS, for example, some eighteen hundred OH-180s will be used as compact substitute for myriads

of electromechanical-relay panelboards and control-wiring connections. Although projects like this one are undertaken in support of the power system, Canadian manufacturers benefit from the resulting transfer of technology through broadening of their manufacturing expertise, and development and pursuit of new marketing opportunities.



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RESEARCH ANNUAL



The insulators shown on the cover are being tested in the Research Division's new, fully-instrumented, temperature-controlled environmental test chamber. This unique facility is capable of simulating fog, freezing rain and icing conditions continuously while the performance of insulator strings, energized at up to 370kV, is monitored.

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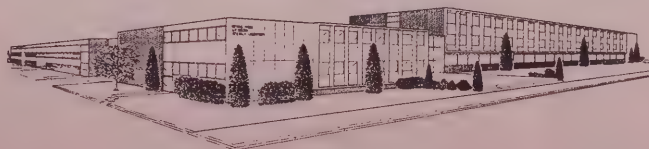
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The Research Division of Ontario Hydro began as a small



group that was formed in 1912 to meet requirements for standards and testing, and since that time it has grown with Hydro in experience, size and reputation. The Division cooperates with other parts of the Corporation to provide research and development related to the engineering and operation of the power system and the utilization of electricity. It is a comprehensive, fully integrated and modern research establishment.

1971-1972

VICE-PRESIDENT'S MESSAGE

Ontario Hydro, by making available a reliable and relatively inexpensive supply of electrical energy, provides significant support for the economy of the Province of Ontario. It is supported in turn by a research function that is a recognized world leader in electric utility research. Traditionally, Ontario Hydro's research has been directed at maintaining the high standard of service that its customers have come to expect. Recently the Research Division has also begun playing a much more active role in support of Hydro's industrial customers.

The Division's Electrotechnologies Laboratory was established to help Ontario manufacturers evaluate various electrical technologies. Facilities for assessing the technical and economic effectiveness of microwave, infrared, radio-frequency and heat pump technologies are available. This year, a number of Ontario manufacturers took advantage of the expertise offered by Ontario Hydro and, through our Regional Marketing groups, contacted Research Division staff regarding possible applications of these technologies in their manufacturing operations.

We are pleased to be able to assist our customers in this way. Ontario Hydro has a history of transferring technology to the industries of Ontario. We hope that our current efforts will help to improve the competitiveness of our manufacturers.



L.G. McConnell
Vice-President
Power System Program

L. G. McConnell and D. Mills are shown standing in front of a dehumidification chamber that is being used to dry various food products. Research has demonstrated that this efficient drying technology can provide energy savings of over 55 per cent and improve the quality of the final product.





DIRECTOR'S MESSAGE

Nineteen eighty-six was an eventful year for the Research Division of Ontario Hydro.

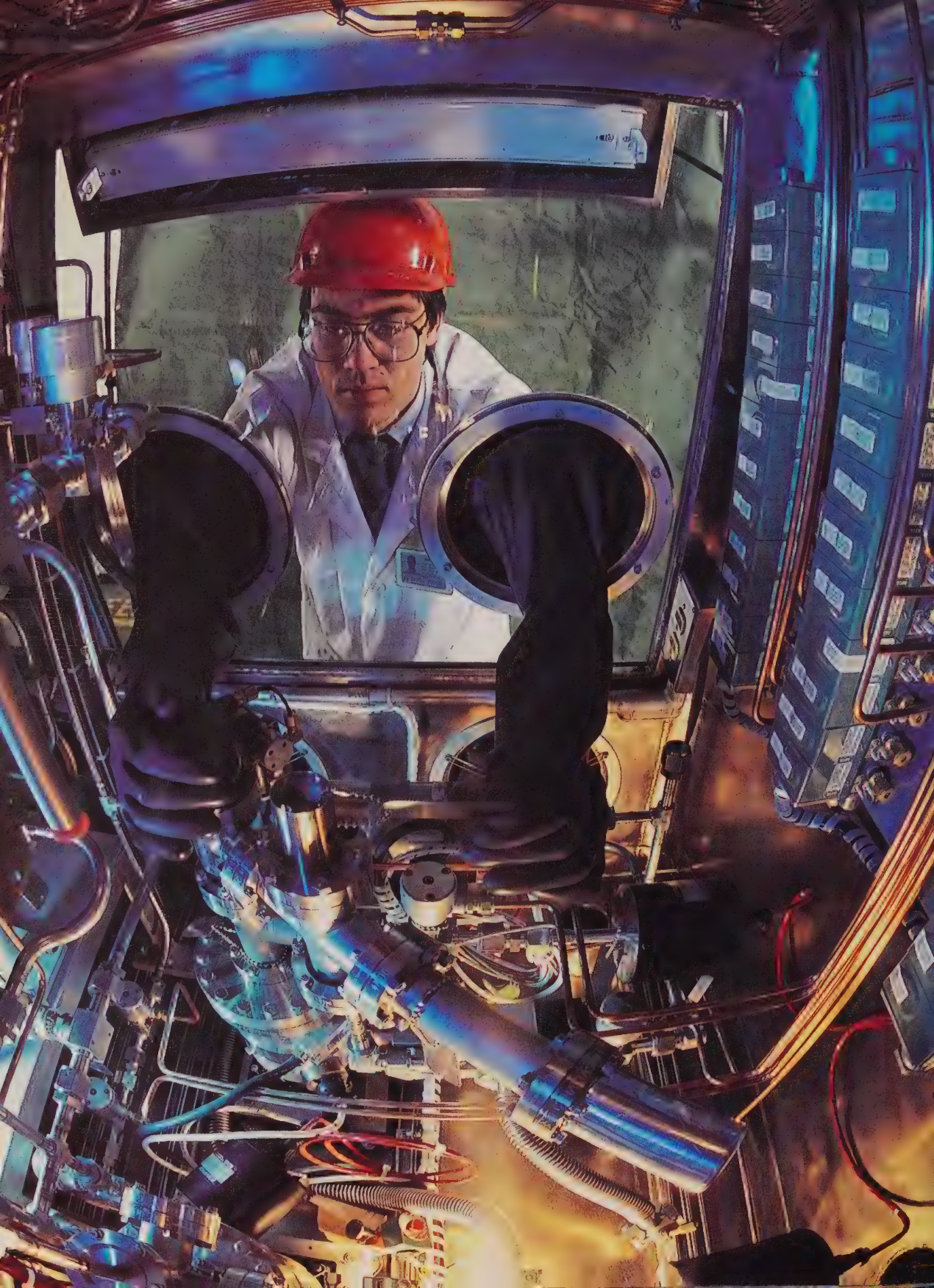
During the past few years, the Research Division has developed a "technical ladder" for its professional staff which will allow the Corporation to recognize scientific and engineering expertise of staff members without burdening them with administrative responsibilities. In 1986, the technical ladder was implemented and five appointments were made. The senior staff members affected by this change will now be able to devote more of their effort to initiation and accomplishment of critical research.

Early in 1986, our new Heavy Mechanical Test Building was completed and fully occupied. The building has a gross floor area of 6300 square metres and significantly expands the mechanical testing capabilities of the Research Division. The main laboratory has a large strong floor with a capacity of 1500-kN tension, compression and shear per anchor bolt, and an environmental test chamber with a temperature range of -60°C to 100°C , which is equipped with a strong floor suitable for static and dynamic testing. The building also houses an indoor conductor dynamics laboratory, which accommodates one 50-m and one 100-m test span.

The Research Division Awards Program, started in 1985, was implemented in 1986 and the first annual awards presentations reception was held. The awards are designed to give management an opportunity to recognize outstanding contributions, both technical and non-technical, made by staff of the Division.

During 1986, the Research Division maintained the high calibre of work that has characterized its performance in the past. I would like to take this opportunity to recognize the expertise and commitment of the Division's managers and staff.

D. Mills
Director of Research



Ontario Hydro has a large, diverse and effective resource of generating facilities. In 1986, the Corporation generated 119 356 687 MW·h of electricity. This included 58 213 420 MW·h generated at nuclear stations, 23 966 988 MW·h generated at fossil-fired stations and 37 176 279 MW·h generated at hydro-electric stations.

The nuclear units, of the CANDU design, are certainly among the most effective and reliable in the world. They generate energy at low cost, their safety record is good and their radiation emissions are well below the limits set by regulatory authorities. Research Division efforts directed towards maintenance and improvement of the effectiveness of these units include non-destructive evaluation of reactor fuel channels, and studies of materials integrity, structural integrity, decontamination in preparation for reactor maintenance and the separation, storage and ultimate utilization of tritium, a by-product of reactor operation.

Most of Ontario Hydro's fossil-fired units are large and a small defect can cause a costly power outage. The Research Division is responsible for helping to solve problems as they occur and for developing techniques to avoid failures and to extend unit lives.

Significant changes in the design of hydraulic units occur relatively infrequently; these units may therefore involve fewer operating and maintenance difficulties. Research Division projects include monitoring of the performance of large hydraulic structures, development of techniques for predictive maintenance of hydrogenerators, and development of electronic devices such as the digital speed switch for controlling auxiliaries during unit run-up.

Part of a tritium immobilization system, this glove box makes use of vacuum pumps, valves, instrumentation and interconnecting piping to immobilize pure tritium gas for later recovery or permanent storage. The system is part of Ontario Hydro's Tritium Removal Facility located at Darlington NGS.

NUCLEAR

Characteristics and Performance of CANDU Fuel Channels

Studies of the effects of hydride on the performance of fuel-channel pressure tubes (PTs) continued in 1986. There is continuing interest in delayed hydride crack velocities and in the effects of hydride on PT fracture toughness and on hydride crack initiation, blister growth and fracture. Novel techniques for measuring hydrogen contents in PTs are being investigated.

Delayed hydride cracking tests showed that both PT microstructure and thermal history have significant effects on the plateau velocities of crack propagation. However, hydride size and orientation were shown to have negligible effects.

Crack initiation was achieved in four-point bend tests. A test technique is being developed to simulate the effects of increasing hydrogen content in high-stress rolled-joint zones. Zero-clearance rolled joints are being examined in a program funded by COG.

Tests of the fracture toughness of small specimens have shown that large proportions of radial-axial-oriented hydrides seriously embrittle PTs at temperatures below 240°C.

Measurements of the spatial distribution of deuterium in blisters grown in the laboratory were made with an ion-beam microprobe technique developed at Queen's University, and these agreed well with modelled blister growth. The blister-growth results were used in predictions of blister probability for reactors being considered for SLAR and those for which REFAB is likely. A Monte Carlo computer model for these applications, developed in conjunction with Crosscurrents Research, is generating wide interest in the Corporation.

Finite element analysis has shown that the stresses associated with blister formation are strongly dependent on the distribution of hydrogen within the blister. As hydrogen concentration increases, the hydride phase yields and internal compressive stresses decline. Large blisters are believed to crack at a

lower stress because their internal compressive stresses are lower and thus a smaller applied stress is needed to reach a critical tensile value. Ongoing work includes a 3-D finite-element analysis and tests of blisters grown under stress.

The Tube Response After Contact (TRAC) program continued to generate significant information about thermal boundary conditions between contacting tubes and about blister growth and fracture. Tests that simulate contact between a PT and a calandria tube have produced extensive temperature distribution data under various thermal boundary and loading conditions. A PT sample with a known hydrogen concentration is being tested to determine the effects of a growing blister on the temperature field in the contact region. Tests at SPEL using a simulated reactor situation for nine channels produced small blisters on all nine channels and some indication of preferential blister growth. These same tubes are being used to test the performance of the SLAR tool.

At present, only limited corrosion and hydriding data exist for Zr - 2.5wt% Nb PT material. Considerable effort has been spent on development of a fuel-channel-corrosion and hydriding behaviour model for predicting long-term in-reactor performance under both boiling and non-boiling conditions.

In-reactor tests using carrier fuel bundles and out-reactor tests are being performed in a number of coordinated AECL-Ontario Hydro research programs. At the Research Division, tests are carried out in static and refreshed autoclaves under simulated Primary Heat Transport (PHT) coolant conditions to establish the long-term effects of temperature, operating time, type of alloy and impurities, PT surface finish, water chemistry and oxide thickness on corrosion rate and hydriding behaviour of Zr - 2.5wt% Nb. In parallel, post-service examination of PTs is now being made at regular intervals and a computer data base has been established for all data from this source.

Collaborative research programs have been established with Toronto, Windsor and McMaster Universities to

provide fundamental understanding of deuterium adsorption mechanisms and to develop remedial measures for new PTs and PTs now in service.

Studies of the effects of deformation on PT performance continued. Both in-reactor and out-reactor experiments were made to increase our present understanding of the deformation behaviour of Zr-2.5wt%Nb PTs under normal and potential load-manoeuvring operating conditions.

Recent results from a growth study in the DIDO reactor at AERE Harwell indicate that small changes in the irradiation temperature can result in significant changes in both the sign and the magnitude of the strain transients. The implications of these results to the service performance of the PTs are being analyzed.

Nondestructive Evaluation of Reactor Fuel Channels

The fuel Channel Inspection and Gauging Apparatus for Reactors (CIGAR) has been in operation for more than a year and has proven to be very successful and reliable. However, its operation has highlighted requirements for improvement which are now being addressed. These include the development and inclusion of a multiplexer system which will allow additional inspection functions to be undertaken. An inspection system quite similar to CIGAR is now under construction for use in the vertical pressure-tube reactor, CIRENE, in Italy.

A pressure-tube failure at Bruce NGS created requirements for a considerable amount of nondestructive evaluation in 1986. This included development of a 75-MHz ultrasound technique which indicates reliably the presence of tight, shallow defects of the kind thought to be responsible for the failure. The technique is now being used by an operational group to examine all pressure-tube off-cuts and by the manufacturer to inspect all tubes not yet installed at Darlington NGS.

Steam-Generator Corrosion and Cleaning

Tube corrosion under sludge deposits

is the main cause of failure in nuclear steam-generators throughout the world. The area of most interest in our reactors is the sludge pile on the tubesheet.

A test program was carried out to determine the susceptibility of Monel-400 tubing from Pickering NGS to under-deposit corrosion as a result of impurities introduced by in-leakage of condenser-cooling water. A similar study is underway with Darlington NGS Incoloy-800 tubing. Autoclave and loop tests are also being carried out in a study of the effects of temperature, water chemistry and metallurgical conditions on stress-corrosion cracking and crevice corrosion of tube alloys.

A laboratory program is underway to relate the nature and degree of tube degradation to the high-pressure bursting characteristics of the tubes and thus provide better definition of the service limits of degraded tubes. The development of a technique to measure operating stresses and vibrations of steam-generator tubes continued. An ultrasonic probe was optimized for the detection of pitting of steam-generator tubes.

Steam-generator deposits result mainly from ingress of corrosion product impurities with the feedwater. A project to monitor this transport into the steam generators at Bruce NGS B was begun in 1986 and development work was continued on two techniques for the removal of the deposits: high-pressure water jetting for Pickering NGS, and chemical cleaning for Bruce NGS. Final refinements were made to the water-jetting nozzle design to improve flow efficiency. Long-term testing of the corrosive effect of chemical cleaning on steam-generator materials has failed to show any significant degradation.

Corrosion and Fouling of Heat-Exchanger Tubes

Under-deposit corrosion failure of heat-exchanger tubes continues to be a major cause of nuclear unit downtime, particularly at Pickering NGS. The influence of biological activity on the formation of deposits on heat-exchanger tubes and on corrosion is being studied by means of laboratory

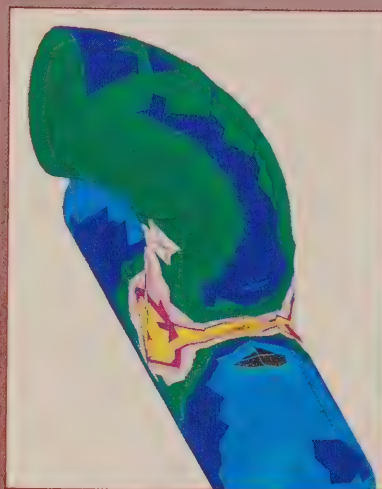
experiments and a test rig system operating at Pickering NGS. A second rig is being built for Darlington NGS. Ultrasonics are being investigated as a means of controlling biofouling.

The influences of temperature, water chemistry, and alloy composition on localized corrosion in a lakewater environment of several candidate heat-exchanger tube alloys are being studied. A wide range of testing techniques, which include electrochemical, immersion and on-site test rigs, are being used to develop correlations between laboratory and in-service performance. This will allow preparation of life estimates for a variety of heat-exchanger-tube alloys.

Monitoring of Large-Diameter Piping in Primary-Heat-Transport Systems

Staff in the Research and Design and Development Divisions are cooperating in experimental and analytical work for a leak-before-break approach to monitoring of structural integrity of large-diameter piping in the primary heat-transport system at Darlington NGS. An extensive program of testing to determine the properties of piping material, welds and forgings has been completed.

A computer portrayal of the operating stresses in a tee junction in the outlet header of the heat-transport system of a CANDU nuclear reactor. This 'fringe' plot was graphically produced with software and hardware provided by Ontario Hydro's Design and Development Division.



For fracture-mechanics analysis, a Ramberg-Osgood representation of A106B tensile data was completed, and a commercially available finite-element program was verified by comparing its output with the results of laboratory testing. Work on three-dimensional, elastic-plastic, finite-element analysis of elbows and tees with hypothetical cracks is continuing.

Detection and Quantification of Leaks in Containment Envelopes

Current practice for location of leaks in the containment envelopes of nuclear power plants requires a commercial leak detection solution to be sprayed on equipment and structural components. Research, cofunded by COG-CAN-DEV, to find more effective detection methods has been in progress for some years.

A leakage catcher was developed which could be used to provide quantitative leakage-rate information. Poly-

ethylene film is draped over the leak site and attached by heat welding or by application of a hot-melt adhesive. The leakage is captured and then allowed to exhaust through mass flowmeters. Leakage rates ranging from 0.1 L/min to 100 L/min can thus be measured.

Testing of Nuclear Process Equipment

At the Division's Nuclear Process Components Test Facility, testing of a large isolation valve for the Bruce NGS A emergency coolant-injection system was completed. The results demonstrated that modifications to motor size, position sensing, and control logic will prevent recurrence of mechanical damage discovered during regular testing of valves installed at the station.

A project was initiated to investigate at reduced scale the rough operation and vibration of PHT pumps and piping systems under unsteady two-phase steam-water flow conditions. The resulting data will improve the analysis of PHT-

system integrity during unusual operating conditions such as depressurization due to a small pipe break.

The development of on-line condition monitoring of PHT pumpsets was advanced by a unique series of laboratory tests on a full-scale machine. Various deficiencies such as unbalance, misalignment, and shaft and bearing rubs were introduced under controlled conditions. The test results were used in developing procedures for detecting these faults with the standard complement of vibration transducers installed on machines at the stations.

Decontamination Studies

There is a continuing requirement for reduction of radiation fields in the vicinity of reactor system components. Studies were carried out in 1986 to improve the CANDECON decontamination process and to develop solvents for the decontamination of surfaces where CANDECON is of limited effectiveness.

A corrosion inhibitor was used in the successful CANDECON decontaminations at Pickering NGS in 1984 and 1985. However, because of its sulphur content, this material cannot be used at Bruce NGS. On the basis of a literature survey and an extensive set of laboratory screening tests, three candidate alternative inhibitors have been identified for further evaluation.

The CANDECON process now in use is relatively ineffective for dissolution of the chromium-containing oxide films on stainless-steel surfaces such as end fittings. A pre-treatment is required to make the oxide more susceptible to dissolution by the CANDECON solvent. A process based on an alkaline permanganate treatment was optimized for use in end-fitting decontamination, and a promising chemical modification to the process has been identified and will be tested further.

Support was provided for the decontamination of the heat-transport systems of Pickering Unit 4 and Bruce Unit 1, and of the moderator system of Pickering Unit 2.

A sophisticated ultrasonic instrument in use to detect and amplify the noise of air escaping through a staged leak in a pipe fitting. The work is part of the development of fast and reliable methods for detecting leaks in the containment envelopes of nuclear stations.



Reinforced Concrete in Nuclear Stations

Under LOCA conditions, the reinforced-concrete components of nuclear-containment structures might be exposed to very high thermal gradients which could cause stressing, cracking and distortion that could affect the function and safety of the structure.

An investigation of thermal gradient effects in reinforced concrete containment structures was therefore undertaken by the Civil Research Department and the Design and Development Division - Generation. Experimental work involved the construction and testing of large-scale models and the gathering of much needed data on structural response. Theoretical work was undertaken to develop more accurate methods of analysis and prediction.

In 1986, testing was completed with the second model and begun with the third and last model. Data obtained up to now supports the findings with the first test model, which indicated that the analytical procedures used previously were somewhat optimistic in predicting the induced stresses. The analytical procedure developed recently, however, has been shown to predict response more accurately, and it is now being used in analyses of various containment structures under actual load conditions.

Tritium Technology

The Tritium Immobilization System has been built and shipped to Darlington NGS for installation in the Tritium Removal Facility. This system receives pure tritium gas from a train of cryogenic distillation columns and stores the gas in metered quantities as a metal tritide on titanium sponge. It is expected to be commissioned in mid 1987.

The investigation of hydrogen permeation through metals has led to the development of two devices. One of these, a prototype hydrogen pump now being evaluated, relies on the unidirectional movement of atomic hydrogen through a composite metallic membrane. The other, an atomic hydrogen monitor, relies on the ability of thin metallic membranes to discriminate between atomic and molecular hydro-

gen that impinges on the upstream surface. This is the only device capable of directly measuring low-energy radial atomic-hydrogen fluxes from the plasma to the wall. It has been tested on the tokamak, TEXTOR, at Jülich, West Germany.

Requirements for techniques to provide safe storage of tritium and to minimize the release of tritium to the environment have motivated studies of the interactions of hydrogen with hydride-forming metals. For the first requirement, the hydriding characteristics of uranium powder and titanium sponge have been studied under a variety of operating conditions. This work has led to the development of 5-kCi and 500-kCi storage beds. For the second requirement, the use of zirconium alloys to remove free or chemically bound tritium from inert gas streams is considered to be a viable approach. Scavenging beds are being developed for this application.

A process is being developed which uses a laser to selectively remove tritium from either light or heavy water streams. The molecules of the working gas, trifluoromethane, strip tritium from molecules they contact in the water stream. When the gas is irradiated by the laser, only the tritium-bearing molecules dissociate; the dissociation products are subsequently removed from the gas stream for further enrichment and storage. Current research activities centre on optimizing the stripping and laser dissociation processes.

Tritium-activated lamps are ideally suited for remote applications where power supply is restricted or non-existent. These lamps use phosphor irradiated by electrons from tritium decay to generate the light and a dye-impregnated plastic to concentrate it. Laser spectroscopic studies have identified the combination of materials needed to maximize lamp brightness.

Hydrogen-isotope separation based on gas chromatography is being developed for possible applications in fusion-reactor gas-streams and tritium laboratory processes. The first application is in separating trace quantities of protium (H_2) from a stream of deuterium (D_2) and tritium (T_2). A novel

development provides a tenfold increase in protium decontamination factor and concomitant increase in throughput as compared with conventional gas chromatographic approaches. The second application is in separating the six isotope species in an equimolar mixture of H, D and T. Laboratory studies have shown that improvements over conventional approaches in both separating power and throughput are feasible.

Control of Water Chemistry

The ability to maintain appropriate chemistry and purity of water in CANDU systems such as the moderator and primary heat transport circuits, and in the irradiated fuel bays is essential for the safe and efficient operation of CANDU units.

Ion-exchange resins have a major role in the chemistry control and purification of water in these systems. Because of continuing inconsistencies in the quality of some of the ion-exchange resins, a detailed quality-assurance program was undertaken to ensure that only resins of acceptable quality are used in our nuclear stations. This program has significantly reduced the number and magnitude of resin-related problems, resulting in substantial cost savings.

Studies of the basic chemistry of gadolinium (a neutron poison) were continued to establish the chemical conditions that would prevent or minimize Gd precipitation in CANDU moderator systems. Also, the causes of poor performance of mixed resins in CANDU moderator systems are being examined by the use of test ion-exchange columns installed in the Pickering NGS B moderator systems.

Carbon-14 Studies

Coordinated by the Carbon-14 Task Group, the Research and other Hydro Divisions made efforts to characterize the carbon-14-containing material released from the annulus-gas systems to the vaults of Units 1 and 2 at Pickering NGS during retubing operations. Examination of a number of samples from different locations has indicated that the material consists of a compound of carbon, oxygen and nitrogen, usually in close combination with iron-oxide

particles. Relatively high specific activity particles have also been found and separated from the iron particles. Some of the Unit 2 particles also show a distinct dendritic morphology and this gives some clue to its formation and deposition. Assistance has been given to the Technical and Training Services Division in developing techniques for the safe removal and containment of the material from system surfaces.

A carbon-14 removal system for the moderator cover-gas was assembled by the Chemical Research Department in cooperation with the Design and Development Division – Generation and NPD NGS. The system, based on a patented process developed by Chemical Research, will be operated at NPD NGS for six months or more to demonstrate its performance in a CANDU nuclear station environment.

THERMAL

Thermal-Plant Life Assessment

Current forecasts of loads and system capacity indicate a long period of continuing requirement for the thermal units now in service on the Ontario Hydro system. Since most of these units are approaching or have exceeded their 100 000-hour design life, careful prediction of the remaining life of critical components and systems in these units has become very important.

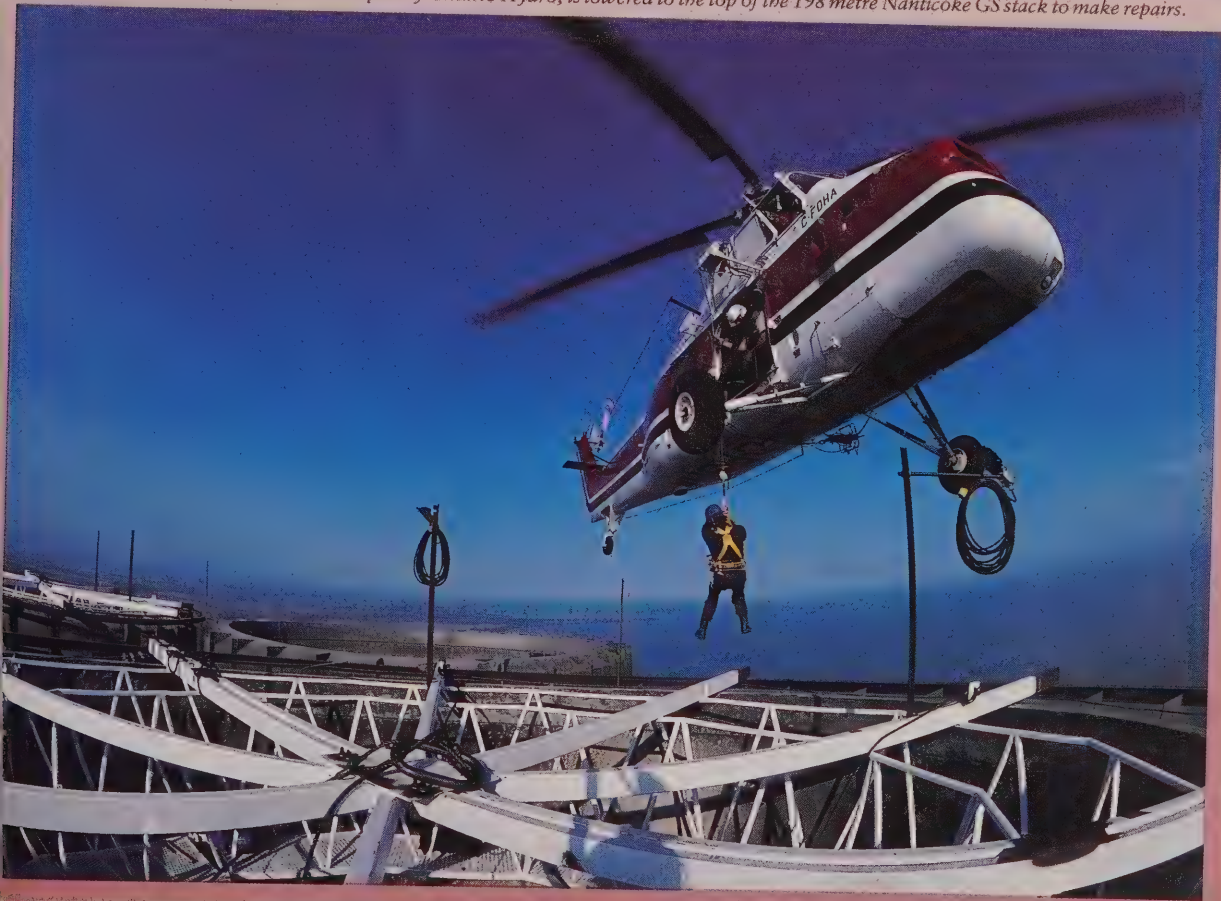
The Research Division played a major part in a life assessment of Unit 1 at Lakeview TGS. A surface replication technique recently evaluated under CEA contract was used for component appraisal and damage detection. Acetate replicas of surface microstructure were made at selected locations and then subjected to microscopic examina-

tion in the laboratory to check for cavities, cracks or excessive structural degeneration. Residual life estimates for large quantities of superheater and reheater tubing from thermal units were made using a refined version of the method based on measured loss of tube-wall thickness.

Creep Life of Major Boiler Components

On the basis of demonstrable conservatism in the original design, considerable life-extension may be feasible for high-temperature headers and steam piping if there is no obvious creep damage such as cracking or swelling. Two approaches to life extension are being explored: improvement in understanding of the stress that controls creep deformation; and accurate prediction of the long-term creep properties of the component material.

A welder, wearing a safety harness developed by Ontario Hydro, is lowered to the top of the 198 metre Nanticoke GS stack to make repairs.



Tests at Research on both uniaxial (tensile) and multi-axial (pressurized tube) specimens of 2-1/4Cr-1 Mo steel have shown that the creep rate of cylindrical-geometry components is best predicted by applying the reference stress based on von Mises yielding to uniaxial test data.

Since this stress is about 15 per cent lower than the mean-diameter hoop stress used in design, a significant degree of design conservatism is clearly indicated. These tests have also shown at that long-term creep behaviour under both uniaxial and multi-axial loading may be predicted by applying the "0-projection" method to relatively short-term test data.

Corrosion-Fatigue of Carbon Steel Components

Thermal and nuclear units differ in component geometries and operating conditions, but metallographic examination of failed components has suggested that corrosion-fatigue in tubes and larger carbon-steel components in these two types of units is basically similar in nature. A review of fatigue in carbon steel exposed to high-temperature water revealed that there is only limited understanding of the crack initiation process and a virtual absence of relevant data. For crack growth, an extensive data base exists for the steels and water conditions used in light-water reactor systems, but its relevance to Ontario Hydro thermal and nuclear units is not known.

A test facility has been built for generating representative corrosion-fatigue cracking in sections of carbon-steel boiler tubing. Cyclic mechanical loading is applied by a servo-hydraulic system and a realistic waterside environment is provided by a high-temperature flowing loop. The facility will be used in a test program that is part of a major EPRI contract on corrosion-fatigue in boiler tubing.

Treatments to Prevent Exfoliation in Reheater Tubes

Uncontrolled release of exfoliated oxide scale from steam-exposed surfaces in superheaters and reheaters can lead to serious mechanical damage to

turbine equipment. However, laboratory tests have shown that when tubes are treated with borate solutions the growth of steamside scale is slowed, scale adhesion increases and exfoliation decreases. On the basis of these results, chemical treatments have been developed to reduce exfoliation in superheater and reheater tubes. The field testing of treated 2-1/4 Cr-1Mo reheater tubes is in progress in Unit 1 at Lambton TGS.

Combustion Research

The Research Division's Combustion Research Facility (CRF) was substantially upgraded during the past two years to facilitate both combustion research and fuels characterization work under conditions that simulate full-scale boiler operation.

Combustion performance, pollution potential, slagging and fouling properties and ash characteristics of a beneficiated coal from western Canada were evaluated at the CRF and compared with the characteristics of a high-volatile bituminous coal from the eastern US. The effects of combustion additives in improving carbon utilization at Ontario Hydro's thermal stations were also investigated. A proprietary catalyst dissolved in a petroleum-based carrier was injected with the coal stream at rates ranging from 0.6 to 1.8 mg per kg of coal. The effect varied with rate of catalyst addition; carbon in ash was reduced from baseline levels by 15 to 50 per cent. The additive did not affect ash characteristics, slagging and fouling. Full-scale testing of the additive is planned for 1987.

The spectral characteristics of infrared emissions from coal flames are being examined at the CRF for the Saskatchewan Power Corporation as part of a contract with CEA. The objective is to characterize coal-flame emissions in terms of wavelength, position in the flame, and flicker. The results will be used to look for emission features that will reliably indicate the presence or absence of individual flames in a multi-burner boiler. This research is contributing to the development of new coal-flame scanners with improved performance in boiler control applications. In preliminary measurements, flicker

frequencies have been characterized as a function of wavelength between 2 and 3 microns for bituminous coals and lignite. The original data tapes have been sent to Saskatchewan Power for computer analysis. These measurements show that detailed spectral information can be obtained in the infrared under the difficult conditions that exist in coal-fired boilers.

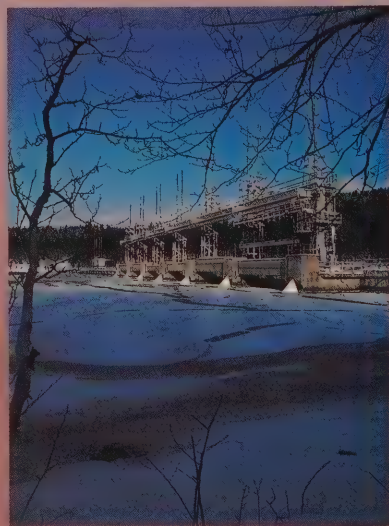
HYDRAULIC

Monitoring the Performance of Major Hydraulic Structures

As part of the Ontario Hydro Dam Safety Program, the Civil Research Department has installed deformation monitoring devices, consisting of inverse pendulums, normal pendulums, wire extensometers and alignment survey grids in major concrete dams at Stewartville, Mountain Chute and Des Joachims Generating Stations.

Evaluation of the condition of the concrete in hydraulic structures is continuing. Selected sites are visited and visually assessed and samples of concrete are obtained by core drilling for examination and testing. Recommendations for repair materials and procedures are drafted.

As part of its Dam Safety Program, Ontario Hydro monitors the structural integrity of mass concrete hydraulic structures such as the McConnell Lake control dam shown here.



Civil Research is setting up systems for remote monitoring of the slopes and foundations of hydraulic structures. Typical projects include assessment of rock slope movements at the Ontario Power GS, measurement of water levels in weirs adjacent to the pumped-storage reservoir embankment at Sir Adam Beck – Niagara GS and determination of foundation drainage flow at Stewartville GS. Data is transmitted from the field to computers at both the Research Division and Head Office where analyses are undertaken. Remote monitoring enables initiation of corrective action at an early stage when necessary.

Monitoring for Predictive Maintenance of Hydrogenerators

Research under contract with EPRI has led to significant improvement in

techniques for planning and undertaking hydrogenerator maintenance. Computer-based monitoring systems have been installed at two generating stations as pilot projects to evaluate the benefits of the program.

This innovation has been made practical by the microcomputer, which brings together signals relating to mechanical, electrical, hydraulic, and thermal performance for comparison and evaluation. The improved data made available to operators in this way is advantageous because maintenance can be advanced if necessary to prevent a defect from becoming a catastrophe, or postponed for a machine which monitoring has shown to be in good condition. This can save immediate costs for maintenance labour and for replacement power from higher cost generators.

Another advantage of electronic monitoring is that the needed data can be transmitted over a single telephone line or microwave channel – important for predictive maintenance of Hydro's many remotely operated stations. For an initial trial, two hydrogenerators – one at Sir Adam Beck – Niagara GS and the other at Robert H. Saunders – St. Lawrence GS – have been fitted with 74 channels of computer-based monitoring for predictive maintenance. These large multi-unit plants were chosen as demonstration sites because it will be easy to expand monitoring to identical units.

More effective monitoring of mechanical vibration of large rotating shafts has been made possible by application of the eddy-current proximity probe, which measures the clearance between rotating shafts and their bear-

A pendulum is being lowered, from the deck of the control dam at McConnell Lake, to measure structural changes within the body of the dam. As part of Ontario Hydro's Dam Safety Program, the Research Division has installed instrumentation in nine hydraulic structures to ensure that stresses resulting from temperature changes and fluctuating water levels are within acceptable limits.



ings without touching the shaft. Similar probes monitor shaft axial position which is the best indicator of impending thrust-bearing failure.

Generator air gap is also measured. This is important because unbalanced magnetic forces can cause "pull-over" with resultant interference between

rotor and stator iron. This causes heat, sparks and debris which soon destroy the winding and core on both rotor and stator.

The well planned predictive maintenance made possible by these developments is an essential part of any program to prevent failure and extend

the life of large electrical machinery and so defer enormous expenditures for equipment replacement.

Digital Speed Switch

While a hydraulic generator is being brought up to speed prior to being connected to the power grid, several pieces

After stabilization of the rock-cliff at Ontario Power GS, 250 meters downstream from Horseshoe Falls, this area of the cliff is being monitored by sliding micrometers and remotely-read computerized extensimeters. Stabilization is achieved by use of shotcrete, cable anchors and pressure-relief holes.



of auxiliary equipment must be turned on and off as the unit reaches certain speeds. A microprocessor-based Digital Speed Switch (DSS) has been developed to improve the reliability of such controls on hydraulic generators. The DSS contains four control relays, each of which can be set to pick up and drop out at various percentages of the generator's rated speed. The use of digital setting techniques simplifies the setup procedure and improves the accuracy of each set-point.

OTHER STUDIES

System and Component Reliability Studies

Ontario Hydro is obliged by its mandate to provide its customers with a reliable supply of electric power. System and component reliability has therefore always been a concern, and reliability evaluations have been carried out in many applications by several parts of the Hydro organization. The Research Division has contributed to this effort by developing theoretical foundations for some of the applications and by performing diverse studies to assist the planning, operating and maintenance functions.

Standby Combustion Turbine Units (CTUs) at Ontario Hydro's nuclear generating stations are designed to supply power under emergency conditions. The serviceability of a CTU is tested at regular intervals in a procedure that includes start-up, operating for a specified period, and shutdown. Since data collected from the tests are incompatible with commonly used reliability models, a new model was developed, and new performance indices were defined specifically for this application.

Improvements in generating unit reliability will come from better diagnostic testing and more timely preventive maintenance. For a number of years, the Research Division, in cooperation with the Thermal and Hydraulic Generation Division and CEA, has been developing a Partial Discharge Analyzer (PDA) test to warn of deterioration of generator insulation. This PDA test has already significantly improved the reliability of hydrogenerator winding on the Ontario Hydro system and the systems of dozens of other utilities. Progress has been

made in applying the same technology to turbo generators.

Components in complex engineering systems, such as pressure tubes in a CANDU reactor, are tested at regular intervals to ensure safe operation. Some test methods are accurate but costly and time consuming; others are simple but less accurate. A practical test procedure may use the simple method to single out suspect components, further test them by the accurate method, and then repeat the process as necessary. A model was developed to predict the reliability of such a test procedure.

Defect and Failure Analysis

Environmentally assisted fatigue cracking has occurred both in high-strength stainless-steel turbine blades and in the carbon-steel, primary-heat-transport piping of nuclear plant. Holographic techniques have successfully identified the areas on the turbine blades that are most highly stressed and therefore susceptible to cracking. Protective surface coatings or more resistant alloys can be used in these areas.

A double-exposure holographic method is now being developed to identify the more highly stressed regions in pressurized components and thereby direct ultrasonic inspection to the higher risk areas.

Environmental Qualification of Station Equipment

Simulation of the effects of aging and exposure to heat, humidity, radiation, dust and seismic loading is sometimes necessary in tests to ensure that critical equipment will withstand local environmental conditions and be capable of performing important safety functions throughout its design life. The Research Division has developed facilities for artificially aging samples of material or pieces of equipment and for testing equipment under extreme conditions. Important test facilities include environmental chambers with temperature and humidity control, ovens for accelerated aging, seismic shaker tables, and chambers for simulation of the high temperatures and steam pressures that might be encountered during a LOCA or a main steam-line break.

In 1986, the Research Division carried out environmental qualification and seismic qualification studies on sensitive, safety-related equipment for the Darlington NGS project. This included cables, emergency power-system relay panels, terminal blocks and programmable controllers. Facilities for this kind of work have been improved by the commissioning of a large-capacity LOCA-simulation chamber and by modifications of the LOCA-chamber control system that permit tracking of complicated temperature and pressure time histories.

Artificial Intelligence

Several expert systems are being developed to streamline various aspects of power-system operations. One of these, which involves cooperative effort between Ontario Hydro and Stanford Research Institute International, under contract with EPRI, will assist in the diagnosis of generator faults. Another is designed to give advice on the type of coating most appropriate for a particular surface and still another, to assist in interpreting the results from eddy current probes used in the inspection of nuclear pressure tubes.

Work is also being done on the application of machine vision and other artificial intelligence techniques to robotic welding.

Seismic Hazard Studies

Ontario Hydro is cooperating with the Atomic Energy Control Board, the Geological Survey of Canada, the Geological Survey of Ontario and the Institute for Remote Sensing in a program to improve the methodology for assessing seismic hazards in southern Ontario. The objective is to improve capabilities for seismic assessment of areas of scarce seismic data by evaluating the near-surface geological conditions such as rock stress and glacial rebound rates. In conjunction with this, Civil Research is investigating the stress field in near-surface geological formations in Prince Edward County. The study will provide direct measurements of rock stress in the vicinity of geological faults and field data on stress-induced failure in rock excavations.

Ontario Hydro's facilities for power delivery include about 27 000 circuit-km of transmission line, 100 000 km of distribution line, and large numbers of transformer, switching and distributing stations.

Current research in the area of power delivery systems includes applications of probabilistic techniques in line and station design, study of conductor vibration control, improvement of the reliability of gas-insulated substations, improvement of power-system stability, improvement of safety in overhead and underground distribution, analysis of transient energy voltages and investigation of the reliability of distribution cables.

TRANSMISSION

New Techniques for Transmission Line Design

The Research Division has made significant advances in applying probability methods to transmission line design. These include development of wind, ice and wind-on-ice load distribution, with the random variation of these loads taken into account; design and reliability evaluations of wood-pole distribution systems; uprating of existing transmission lines; models that generate meteorological data for medium- and long-term periods from relatively short-term records; and management of wood-pole distribution lines.

In 1986 development was completed of a computer program which uses a province-wide data base for meteorological loads in the design of wood-pole lines and the uprating of existing transmission lines. Work was completed on a CEA-sponsored project to establish a nation-wide data base for applying probabilistic methods to distribution

The Canadian Standards Association is developing new fall-protection standards and revising existing ones, based on Ontario Hydro test methods, basic research and application of equipment. Here, a maintenance man in prescribed fall protection equipment is grounding-out a single-circuit 115-kV transmission line section.





systems. Probabilistic models of wind, ice and wind-on-ice loads were developed for an EPRI guide on reliability-based design of transmission lines. An international symposium on probabilistic methods applied to electric power systems was sponsored by Ontario Hydro, CEA and EPRI, and held in Toronto. This drew 180 delegates and 64 papers from 20 countries.

It is expected that by the early 1990's, a number of high-voltage underground cables in the Toronto and Hamilton areas will be loaded, in emergencies, to near their currently defined maximum capabilities. Since five years are required for planning, engineering and construction of new facilities, the capabilities of the existing system are under review. A task group consisting of representatives from the Research, System Planning and Transmission Operations Divisions has undertaken to identify and implement the methodology to accurately rate the load carrying capability of the existing underground cable circuits in a way that will reduce the risk of damage or failure of cable by overload, but fully utilize the available capacity and so possibly save on the cost of building new facilities.

The proposed methodology involves a probabilistic approach to the estimation of cable ampacity that takes into account the variability of ambient and backfill parameters. Field evaluation of the backfill parameters using the Research Division's Thermal Property Analyzer is a key element of this study.

Conductor-Vibration Control

The conductors of overhead transmission and distribution lines are subjected to continuous vibration by the wind. Usually the oscillations are not severe and there is no significant damage by wear and fatigue of conductors and hardware during the 30-year design life of the lines. However, vibration sensitivity increases with increase in conductor tension, and measures now available for vibration control are effective only up to tension levels slightly higher than those now in use. Consequently, there are practical limits to modifications in line design for purposes of economy, such as use of longer spans.

There are three basic types of conduc-

tor oscillation – aeolian vibration, wake-induced oscillation and galloping. Aeolian vibration is a low-amplitude effect in the 10 to 70 Hz frequency range, which is caused by vortex shedding of the wind and can lead to significant damage at support clamps. Wake-induced oscillation in bundle conductors is a result of buffeting of the leeward conductor in the wake of a windward conductor. When buffeting occurs at or near a lateral resonant frequency of a subspan, high-amplitude motion can occur, causing clashing of the subconductors and wear and fatigue at support clamps. Galloping is a high-amplitude, low-frequency vertical motion of as much as 10 metres peak-to-peak that is a result of the effects of wind on an aerodynamically unstable profile created by accumulation of ice on single or bundle conductors. This motion can cause flashovers between conductor phases, wear and breakage of conductors and hardware, loosening of tower bolts and breakage of tower members. Research into techniques for amelioration of all three conductor oscillation phenomena is in progress.

For control of aeolian vibration, a range of alternative designs of vibration dampers is being studied in the Division's newly established 90-m span room. The investigations are to determine their relative damping performance in the range of vibration amplitudes and frequencies encountered in service on four-conductor bundles and overhead ground wires.

There have been a few recent indications of damage in bundle conductors, but wake-induced oscillation is generally kept within acceptable limits by use of spacer-dampers distributed along the bundle span. However, the standards for placement of these spacer-dampers on Ontario Hydro lines have developed through evolution and only one local supplier is qualified to meet the purchasing specifications. Consequently field trials of several alternative makes of spacer-dampers, placed according to the suppliers' guidelines, have been carried out. Monitoring indicates that most of these other spacer-dampers have adequate capacity to reduce vibrations. Tests of other aspects of spacer-damper design leading to qualification of other suppliers are planned.

Galloping studies are continuing with field trials of control devices on distribution lines and on single- and bundle-conductor transmission lines in Ontario and throughout Canada and in the United States and several European countries. The CEA is sponsoring two programs: "Control of Distribution Line Galloping" and "Field Trials of Galloping Control Devices for Bundle Conductor Lines". These field programs involve trial installations of four control devices: interphase spacers, air-flow spoilers, aerodynamic dampers and detuning pendulums. These devices are monitored, during wind and icing events causing galloping, by observers equipped with movie cameras who compare the performance of conductor phases with the control devices installed with the performance of untreated reference phases. The field data are then analyzed and added to the growing data bank on each device.



A full-body fall-protection harness consisting of leg straps, a waist belt, shoulder straps, and a shock-absorbing lanyard, is worn by CN Rail workers involved in the erection and maintenance of telecommunications towers. The equipment is based on that used by Ontario Hydro workers.

Up to now statistically supportable results have been accumulated for only the detuning pendulum on single-conductor transmission lines and these confirm that the device reduces galloping by at least 70 per cent of the maximum theoretical amplitudes.

Gas-Insulated-Substation Research

Ontario Hydro's continuing program of active research to improve the reliability of gas-insulated substations

(GIS) is now addressing some of the fundamental processes active in SF₆-insulated systems. The importance and complexity of these investigations has encouraged international cooperation. They include:

- Development of a theoretical model which predicts the inhomogeneous-field breakdown voltage in SF₆ as a function of electrode configuration and pressure to an accuracy of 5 per cent. This project, partly funded by CEA, involves intensive cooperative effort among six laboratories scattered throughout the world. Research underway has improved understanding of the physics of SF₆ breakdown and promises to unravel the complex interactions between high-frequency transient over-voltages and failure probability. Better designs and test techniques will result.
- Investigation of the fundamental limitations to the quality assurance of GIS spacers. This project is funded by EPRI. It involves four research laboratories and four GIS manufacturers in studies of the fundamental failure mechanisms of GIS spacers and in development of quality assurance measures which will ensure spacer reliability as designs evolve.

Other GIS-related research conforms to Ontario Hydro's needs by emphasizing diagnostic techniques and life-extension. This has resulted in the development of gas-analysis techniques, and in studies of moisture dynamics, spacer refurbishing and means for protecting GIS/cable interfaces during GIS faults.

The success of past efforts and the promise of continuing research along these lines is resulting in wide interest among other utilities that use GIS.

Power-Frequency Flashover of Iced 500-kV Insulators

A number of 60-Hz flashovers of line-suspension and station-post insulators occurred on the 500-kV transmission system in southern Ontario after a period of freezing rain last winter. Most of these flashovers occurred in heavy fog and during a sustained rise in tempera-



A station bus structure is subjected to forces from a drop-test mass that simulate inductive forces resulting from opening and closing of disconnect switches. The wrapping of steel chain duplicates the weight of ice build-up on the bus.

ture from a few degrees below to a few degrees above freezing. Because of the seriousness of this problem, the Division's high-voltage fog-chamber has been extensively modified to enable full-scale testing of insulators under simulated wintertime conditions during the summer months. A controlled test method has been developed to study the performance of lightly contaminated and iced 500-kV insulators, as the temperature is raised in a high-humidity ambient. In cooperation with other divisions a major program is underway to evaluate alternative insulator designs for future 500-kV lines and stations and procedures to improve the reliability of existing insulation.

Power System Stability and Integrity

Continuing efforts to relieve power-delivery constraints imposed by delays in the construction of transmission facilities give high priority to studies of the stability of the bulk power system.

Advanced excitation controls developed by the Research Division are in operation at Bruce NGS and Nanticoke TGS, and power-system stabilizers are now being applied to all units at Pickering NGS. Use of these controls, possibly in combination with tuning of turbine-governor controls at Bruce NGS, will provide additional damping for low-frequency modes of oscillation and thus allow increased utilization of new generating capabilities. In conjunction with the System Planning Division, tools and models are being developed to accurately simulate the existing power system and to allow the assessment of advanced control strategies.

Foreign delegations continue to request Ontario Hydro's expertise in the areas of excitation systems, stabilizers and power-system-stability problems. Computer models for the excitation systems of some of the generators on the power system of the Volta River

Authority in Ghana are being developed and validated by on-site tests.

A system that will use modern digital technology to assist in maintaining acceptable power-system integrity in an environment of aging and increased loading of equipment is at a preliminary stage of development. The system is intended for installation at substations and would provide an overlay to assist conventional protections in making more intelligent decisions. It would also provide detailed and intelligent monitoring for early warning of substation equipment failure.

The ability to monitor system frequency continuously and record variations that occur during disturbances has been enhanced by development of the Microprocessor Digital Frequency Recorder (MDFR). Data stored by the MDFR in an internal memory can be retrieved over standard telephone lines for analysis at a central location to verify the operation of frequency-responsive relays, to check the response of generator-governor controls, and to confirm the results of computer-based system stability studies.

To date, eight MDFRs have been made and four of these are being used by US utilities.

Grounding Studies

Grounding systems protect utility employees and other people from hazardous voltages that may be generated temporarily in fences, structures and buildings when insulation fails or conductors fall to the ground.

At urban stations, grounding systems of conventional design are expensive to build because of constrained size. Fortunately, high-voltage and distribution cables used in urban areas are particularly effective in mitigating the ground potential rise. Simplified methods have been developed to allow inclusion of the beneficial effects of these cables in design calculations.

The steel enclosures of many high-voltage cables are insulated from ground and maintained at a slightly negative potential to prevent corrosion. During recent power-system faults,

there was sufficient arcing between these enclosures and grounded steel structures to cause oil leaks and one serious fire. Measurements made to determine why the existing protective device, a polarizing cell, and its installation are not always effective showed that the impedance of the connecting lead is often too high. A supplementary protector and better analytical tools are being developed.

Intentional power-system faults or hand-cranked Meggers have been used previously in testing the performance of grounding systems, and these techniques have resulted in potentials which are either so high that they are hazardous or so low that they provide poor resolution. However, Ontario Hydro has developed a medium-power method of testing which uses a gasoline-driven portable generator, a frequency slightly higher than 60 Hz and digital network analyzers. This method separates the test signal from background noise and allows accurate measurement of quantities that are normally difficult to assess, such as step-and-touch voltages, interference in communication circuits and current splits in distribution-feeder neutrals.

DISTRIBUTION

Overcurrent Protection of Pad-Mounted Transformers

In underground distribution, transformers are often installed on concrete pads at grade level. Careful consideration must therefore be given to the design and maintenance of overcurrent protection devices to avoid hazards to people who might be close to a transformer when a fault occurs. Ontario Hydro is contributing to improvement of public safety in this field.

Investigations by the Research Division have identified the mechanisms that lead to hazardous failures of the dry-well-canister fusing systems that are used for transformer overcurrent protection by many utilities and have established which products and maintenance procedures are most effective in avoiding this kind of failure. Under a CEA contract, the electrical and mechanical withstand capabilities of current-limiting fuses for pad-mounted transformer

applications have been determined. Failure of current-limiting fuses can be avoided if these withstand capabilities are not exceeded.

Pad-mounted transformers purchased by Ontario Hydro in the near future will be equipped with an under-oil, current-limiting fuse and an oil-expulsion fuse. The Research Division is developing testing techniques and specifications to ensure the safety and reliability of these devices. For the longer term, however, use of an entirely new development, the Fault Current Diverter (FCD), may be considered. In contrast to fuses, which interrupt the fault current, the FCD is designed to create very rapidly a bolted-type short-circuit connection across the input terminals of the transformer. This almost instantaneously diverts the fault current away from the failed transformer to avoid a possibly hazardous incident. The system fault is subsequently cleared without harm by remotely located and relatively slowly acting conventional apparatus, such as line fuses and reclosers.

Analysis of Transient Recovery Voltages in Distribution Systems

The transient recovery voltage that occurs across a switch as it interrupts current is a critical parameter in the design and specification of switches. In recent years, however, switches have been built with less ability to withstand transients in order to reduce costs, and calculation of the maximum transient that a particular switch can expect to encounter is becoming a prerequisite to purchase and installation.

Analysis of transient recovery voltages has been done on transmission systems for many years, but in distribution systems the techniques required for modelling are quite different. New modelling techniques have been developed for distribution systems and the accuracy of these techniques has been verified by performing staged-fault tests on operating distribution systems, and measuring the transient voltage across a switch as it interrupts the fault current. The load has been the most difficult component to model because of its large variation in size and in type of equipment. However, a reasonable level of



This automatic test machine measures the breaking resistance of wood transmission and distribution poles up to 21 meters in length. It can be adapted to accommodate poles of greater length.

agreement between the calculations and the measurements of loads has been demonstrated.

Personal-computer programs have been developed to facilitate use of these modelling techniques by utility distribution engineers.

Safer Distribution and Subtransmission Lines

Catastrophic failures of porcelain horizontal line-post insulators on overhead distribution lines have led to a moratorium on climbing wood poles with armless framing. However, working from an aerial bucket is not much better as this does not eliminate hazards from broken insulators. To make overhead lines safer, new lightweight, polymer, line-post insulators are being developed as a replacement for porcelain insulators. When properly designed and applied, the polymer line-post insulator has the potential of preventing line drops. A draft specification has been developed and field trials at 44 kV are underway. Studies to develop understanding of the long-term static fatigue behaviour of the fibreglass core are in progress.



With support from Ontario Hydro's Distribution Systems Division, the Research Division is developing a comprehensive program for increasing the reliability of transmission and distribution wood-pole lines. The effects of local weather conditions are being considered and means for more realistic evaluation of individual pole strength established.

Reliability of Distribution Cables

When polyethylene insulation technology was adopted for distribution cables in the 1960s, it was assumed that cable life would be similar to that for oil-paper designs; that is over 30 years. However, it was soon discovered that high-molecular-weight polyethylene cables, adopted initially by American utilities, were adversely affected by moisture ingress, and had to be replaced after only 10 years of service. Subsequent widespread adoption of improved insulation, cross-linked polyethylene, which because of its higher thermal rating is the type now widely used in Canada, has provided better performance. Even so, there is still concern that these cables will not last for 30 years and the problem is being addressed by the industry on several fronts.

In Ontario Hydro and the municipal utility systems, investigations of cable failures have identified problem areas

that can be alleviated by practical approaches. For example, voids and contaminants from manufacturing have been found in failed cable. Improved inspection services may therefore be helpful in producing longer-life cable. Also, improper handling can damage insulation, and storing cables with the ends uncapped allows water to enter and initiate a water-treeing failure mechanism.

A technique for recording failures has been developed which will facilitate identification of cable problems as they arise. The recorded data will serve as the basis for development of an optimum cable-replacement program.

Wood-Pole Management

A program to apply destructive and nondestructive testing and probabilistic analysis in evaluating wood poles on the distribution system has been initiated. These techniques will provide more precise and more complete testing of poles

and will weigh the probabilities of coincidence of high loads and low strengths. Implementation is expected to improve the reliability and reduce the operating costs of the distribution system.

A test machine has been developed and built which automatically tests poles at bending loads of up to 1700 kN-m. In its present configuration, the machine tests poles up to 21 m long, but it can accommodate longer poles. Non-destructive evaluation (NDE) methods now in use for wood poles are highly judgemental and provide no strength values. However, the new wood-pole NDE apparatus is designed to determine actual strengths of poles now in service on the system.

Probability analysis will be used to predict the reliability of distribution lines on the basis of the data developed by the NDE and pole-strength tests. The analysis will also provide a basis for determination of requirements for pole inspection, retreatment and replacement.

Electricity can be converted to many forms of energy, and used in various applications with finer control and better efficiencies than are generally achieved with processes driven by fossil fuels. In Ontario, these benefits are compounded by electricity costs that are lower than in most other parts of the world.

To promote optimum use of electricity and thus improve the effectiveness of industrial and commercial customers and the comfort, convenience and economy of residential customers, Ontario Hydro participates in the development, evaluation and demonstration of electrically based processes. The Research Division carries out a large part of this work, cooperating with other parts of the Hydro organization, and with CEA, other industrial and professional associations, government and consumer agencies, and individual customers.

INDUSTRIAL

Ontario Hydro cooperates actively in the development and demonstration of efficient new electrical processes in order to improve the competitive position of Ontario manufacturers.

Microwave, Radio-Frequency and Infrared Technologies

Industrial applications of technologies for production and use of energy in various parts of the electromagnetic spectrum are increasing each year. These include the microwave, radio-frequency, infrared, ultraviolet, laser and electron-beam technologies. Each of these has characteristics suitable for specific classes of application and all lead to general improvement in rate and quality of output and efficiency in use of energy and space.

The Research Division has established versatile test facilities to provide first-hand information on the performance of microwave, radio-frequency and infrared devices for potential new users. These facilities are being used to demonstrate existing applications of each technology and to develop new applications by allowing users to investigate the effects of changes in composi-

tion and manufacturing techniques on product quality and cost.

As part of the corporate marketing effort, the Division assists Ontario manufacturers in selecting and optimizing appropriate electrical technologies to meet specific requirements. Requests for assistance of this kind have covered a wide range of processes that include the drying and sintering of ceramics, deactivation of enzymes in foods, and curing of polymers.

Heat-Pump Drying

Tests and laboratory analyses conducted in cooperation with Ontario industries have shown that heat-pump dehumidification has significant advantages as a process for drying wood, thread, fruit and cardboard tubes. This process first cools and then reheats air that has passed through a drying chamber. The cooling condenses water vapour and the heating returns to the air energy that was extracted during cooling and condensation. This provides hot, dry air for recirculation to continue the process. Drying times are comparable to those for conventional drying systems, but energy consumption is substantially lower.

Ontario Hydro has established a unique test facility that generates information for customers on the use of industrial heat pumps in drying applications. Knowledge of the drying characteristics of a specific product obtained from this facility permits a prospective user to select a heat pump with the best compromise in capital and operating costs and drying time.

Industrial Heat Recovery

A heat pump can produce low-cost process heat by recovering and upgrading heat lost during manufacturing processes. Quite often, recoverable waste heat goes literally down the drain. However, "liquid-to-liquid" heat pumps utilize this energy to preheat boiler-feed

As shown by laboratory testing and analyses performed in cooperation with the Ontario furniture industry, heat-pump dehumidification offers a significant cost advantage in the drying of high quality wood.







Shown here is a microwave system which is used for continuous drying of ceramic fixtures. The Research Division has been working to transfer new electrotechnologies to various manufacturers in Ontario.

water or to produce low-pressure steam. A test loop, designed to simulate typical industrial processes, is being built for use in evaluating a 100-kW conventional water-to-water heat pump and a 40-kW advanced steam-raising heat pump in 1987.

Advanced Ceramics

Research Division activities in the area of advanced ceramics increased in 1986. Microwave bonding of ceramic components in the sodium-sulphur battery was undertaken as part of an effort to assist an Ontario electric-vehicle program and microwave technology was used in investigations of slip drying prior to sintering. The same technology can also be used in drying of conventional ceramics prior to firing.

Ontario Hydro supported research programs at two Ontario universities. These included, at Queen's, development of one plasma process for production of fused silica and another for production of silicon carbide, silicon nitride and composites of these materials. At McMaster, development of a low-temperature-steam electrolysis cell based on conducting ceramic components was undertaken.

A major study, carried out by the

Research Division for CEA, examined the impact of advanced ceramics on electric utilities from the point of view of industrial load associated with the processing of these materials. The study was eventually extended to cover the impact of traditional ceramics.

Ontario Hydro was instrumental in the formation of the Canadian University - Industry Council on Advanced Ceramics in 1986.

Electrochemical Synthesis of Ethylene Glycol

In 1985 Ontario Hydro completed a study, partly funded by CEA, of the possible and likely impacts of new electrochemical technologies on demands for electricity. One recommendation was for construction of an electrochemical pilot plant where new processes could be developed and demonstrated at pilot level to establish their economic feasibility and environmental acceptability. Planning, design and initial construction are now underway.

Initially, the facility will be used for demonstration of the electrochemical process for synthesis of ethylene glycol. The process uses electrical energy to convert formaldehyde from any carbonaceous resource to ethylene glycol.

In Phase I of the project, now in progress, a pilot plant is being designed to produce about 20 kg of ethylene glycol per day. In Phase II, to begin in 1987, equipment will be purchased and the pilot plant will be constructed and started up. In the third and final phase, the pilot plant will be operated for two years to optimize the design and operating parameters and to collect representative economic data.

It is expected that after completion of the ethylene-glycol project, the facility will be made available to Canadian industry for pilot-scale studies of new or improved electrochemical processes.

Oxygen Cathode Development

Despite over a century of effort, oxygen evolution and reduction reactions remain among the most challenging problems in electrocatalysis. In industrial processes, typical oxygen evolution and reduction overpotentials range from 0.3 to 0.8 V. A research program aimed at the development of commercially viable reversible oxygen electrodes has been started.

In this complex program, oxygen cathodes using metal-macromolecule complexes as catalysts are being developed, based on the biological principle of oxygen adsorption on hemoglobin. Initial effort is aimed at developing oxygen cathodes for application in the chloralkali industry, the goal being to replace the hydrogen evolution reaction by oxygen reduction. The development of a suitable cathode will result in substantial energy savings in this industry. The same electrodes may find application in aqueous fuel cells and sodium chlorate manufacture.

In order to develop a basic understanding of the electrocatalytic behaviour of the metal-macromolecule complexes, thin films of metals, alloys and metal oxides on various substrates are being fabricated up to several thousand angstroms in thickness using radio-frequency sputtering deposition techniques. Electrochemical characterization of these films is being carried out using standard electrochemical techniques to study the role of these materials on the electrochemical behaviour of heat-treated metal-organic complexes.

RESIDENTIAL

In recent years, much Research Division effort has been directed at electrical safety, energy management, thermal upgrading, ventilation control, heat-pump design and recovery of waste heat.

Heat Pumps for a Cold Climate

Field testing of the prototype air-source residential heat pump developed for use in cold climates has pointed the way toward development and use of a new kind of refrigerant-control system based entirely on electronics. Sensors connected to the heat pump send signals to a microprocessor that computes the proper opening for the expansion valve. Refinement of the controls, including use of a new "stepper-motor" expansion valve, will further improve heat-pump performance in Canadian conditions.

Windows

Experiments undertaken by the Research Division have shown that replacement of ordinary double-pane windows with low-emissivity (heat-reflective) models reduces heat loss by 30 per cent and also improves the ability of the window to tolerate high indoor humidity without condensation on the inside window surface. Under extreme weather conditions, the improved model will allow indoor relative humidities 8 per cent higher than those tolerated by an ordinary double-pane window.

Service Entrances

Design of a special meter-jaw spring clip has been completed and the device has been tested for use in service entrances on the Ontario Hydro system. Introduction of these clips is part of a province-wide program to ensure proper electrical contact in 100A meter bases. This is especially important for good performance in heavy load applications such as electric heating. The clip is a retrofit device that can be installed on an existing meter socket in a few minutes.

Infrared-Linked Thermostat

When baseboard heaters are added to a house after construction is complete, it is often difficult to route wires from the heater to the best place for the thermostat. However, a battery-operated thermostat is under development which will use an infrared link for the control function, eliminating the need for wires between thermostat and heater. Encoded bursts of infrared radiation are transmitted by the thermostat and decoded by a receiver which controls the heater.

Current Sensor for Water-Heater Survey

A small current sensor has been developed for use with commercial power-line-carrier transmitters in a load survey being made by Ontario Hydro's Marketing Branch. Sensors and transmitters will be installed to monitor the power used by water heaters in about 60 suites of a large apartment building. The data will be transmitted over the power-supply wires to a central computer for analysis.

Strategic Conservation and Load Management

In recent years research activities have been directed toward the testing and evaluation of several new heat-pump-based technologies that can provide demand-side solutions to the problems of meeting future energy needs during periods of supply-side constraint.

Laboratory and field evaluations have been conducted on a "bivalent" heat pump that can use natural gas or propane to lessen electrical demand during periods of peak load. The results show this to be a promising Canadian technology.

The capabilities of lake-source commercial-size heat pumps have been investigated for heating and cooling of office buildings at waterfront locations. Although only one installation of this kind is now in operation in Ontario, proper assessment and design

of these systems could make them as popular here as they are in Sweden.

Investigations and evaluations in previous years have indicated a strong strategic-conservation potential and an advantageous demand pattern for ground-source heat pumps in residential and commercial applications. A 100-home field installation and demonstration has therefore been planned for Richmond Hill, a largely residential community north of Toronto. Monitoring of these and other novel heat-pump installations will continue for several more years.

The reliability of all types of heat pumps is being evaluated in a program of computer-controlled testing in the Division's environmental chambers and in a continuing program of national surveys conducted by CEA. The CEA program is indicating a high level of customer satisfaction with heat pumps now installed. Work to address specific Ontario requirements for performance and reliability is important to ensure that heat-pumps achieve their indicated potential as a major contributor to load management and strategic energy conservation.

Activities have been directed also toward the testing and evaluation of a new generation of heat-pump-based devices that provide mechanical ventilation and humidity control to improve indoor air quality. The devices recover a large part of the thermal energy in building exhaust air for use in space and water heating. Waste-water heat-recovery systems were also assessed. These systems are designed to transfer heat from warm waste-water discharges in residential and commercial buildings to the freshwater supply to hot-water storage tanks.

The attractiveness of these relatively new technologies stems from their high efficiencies and load-management potential. Both new and retrofit applications may significantly lower power demand, energy consumption and heating costs. These integrated appliances also simplify the provision of high-quality residential and commercial heating, ventilation and air conditioning services.

The Research Division conducts an environmental research program designed to help Ontario Hydro minimize the impact of its operations on the biosphere and to assist the Corporation in following government guidelines and meeting regulations. Some of the studies being performed involve development of processes and equipment for the control of emissions and effluents from generating stations and related installations. Other important areas of environmental research include the safe handling, storage, and disposal of reactor waste materials, decontamination of oils containing polychlorinated biphenyls, measurement of electric and magnetic field exposures and control of noise pollution resulting from expansion of stations and the transmission grid.

POLLUTION-RELATED STUDIES

Acid-Rain Studies

Two acid-rain research projects initiated previously were continued in 1986. In one, dry deposition, the process whereby pollutants are removed from the atmosphere through contact with the earth's surface, is being studied. Experimental techniques developed earlier were used in 1986 to measure dry deposition rates of SO_2 and NO_2 on three types of surfaces – a carrot field, a snow-covered field and a forest canopy. While full analysis of the measurements is incomplete, it has been observed that deposition rates of SO_2 and NO_2 on snow are very slow, and that NO_2 can be deposited or emitted by crop canopies.

In the other project, the processes whereby clouds convert, redistribute and deposit atmospheric pollutants are being studied. Mathematical models which describe the dynamics, microphysics and chemistry of the main types of clouds have been developed. Computer versions of these models have provided valuable insight into the role of clouds.

Nets are being prepared to collect sockeye salmon smolts in a study, funded by CEA, on the effectiveness of selected behavioural fish-control devices.





Both projects address areas where our understanding of long-range transport of pollutants is less than adequate. By contributing to ongoing research effort in these areas, Ontario Hydro and CEA are helping to ensure that models used to establish source-receptor relationships and set emission control strategies are accurate.

Acid-Gas Emission Control

An acid-gas emission control program has been developed. The overall objective of the program is to provide technological options which allow continued generation of electricity in a cost-effective, reliable and safe manner, and to meet provincial acid-gas emission regulations.

One of the promising technologies to fulfill longer-term needs is sorbent injection directly into the furnace to control SO_2 emissions. This process offers moderate SO_2 removal efficiency, low capital cost, and operational flexibility to meet the varying demands of the acid-gas emission control program. Major bench- and pilot-scale studies on sorbent injection were started. The program is aimed at improving the performance and reducing the cost of sorbent injection technology for controlling SO_2 emissions from Ontario Hydro's coal-fired units. The process is being tested at full-scale in Lakeview TGS Unit 4.

A bench-scale, quartz flow-through reactor has been used to study limestone calcination and sulphation. The effect of limestone composition, gas temperature and gas composition on the extent of these reactions has been examined. Results suggest that the composition of the sorbent significantly affects its porosity, SO_2 capture efficiency, and the ability of the material to withstand deactivation at high temperatures.

The pilot-scale studies are being conducted at Ontario Hydro's 640-MJ/h combustion research facility. In 1986 more reactive sorbents and sorbent additive mixtures were evaluated and process variables optimized. Also being studied to further enhance process performance are moisture injection upstream of the electrostatic precipitator (ESP), slurry injection into the fur-



At various levels up to thirty meters above a forest canopy, researchers measure the concentrations of sulphur and nitrogen oxides and other pollutants in the air.

nace, waste activation and recycling. Pilot-scale data compare well with full-scale test results. Thus the information generated on the pilot-scale proved to be applicable in the design, implementation and optimization of full-scale test programs. The process produces a waste that is finer than ash from coal and about twice the amount. The waste contains ash, calcium sulphate, and up to 40 per cent quick lime. Currently, efforts are being directed toward fixation and stabilization of the waste material by blending with appropriate amounts of water to render it suitable for landfill disposal.

Studies are also in progress to improve the performance of ESPs so that they can handle, without major upgrades, the increased dustloadings and changes in dust properties that result from sorbent injection and spray dryers.

As part of the short-term objective to ensure that Ontario Hydro is an informed buyer of commercially available acid-gas control technology, a study has been initiated to select a flue-gas desulphurization (FGD) process for Lambton TGS and to prepare a general

environmental assessment program on four different FGD technologies for possible use at Lambton, Nanticoke and Lakeview TGSs.

In addition, design and operating problems, associated with the alternative "closed-loop" operation for the wet FGD processes are being reviewed with emphasis on resolving the difficulties of maintaining water balance. Where appropriate, technologies for wastewater treatment will be examined. Data on relevant physical, chemical and leaching characteristics of the solid wastes that may be generated from these processes, and of the wastes from the dry limestone injection process are being assembled. This information is for the Lambton process selection studies as well as for the general program environmental assessments for Lambton, Nanticoke and Lakeview TGSs.

Environmental Studies at Generating Stations

Ontario Hydro conducts ongoing studies to determine environmental effects of construction and operation of generating stations and to evaluate the performance of environmental protection systems in place at these facilities.

These studies include investigations of physical, chemical and biological aspects of the aquatic environment, studies of wildlife and vegetation, and monitoring of groundwater at ash disposal sites. Studies are currently underway at Atikokan, Nanticoke and Thunder Bay TGSs, at Bruce, Darlington and Pickering NGSs, and at sites on the Mattagami and Mississagi Rivers.

The environmental assessments based on these studies ensure that Ontario Hydro's operations are not adversely influencing the environment and that regulatory requirements are being met.

SAFETY IN THE WORKPLACE

Welding Fumes

Welding is a labour-intensive operation that is performed daily by hundreds of workers at various Ontario Hydro workplaces. The physical hazards of welding – heat, radiation and shock – are quite well understood, but there is relatively little practical information about the potential health hazards of welding-generated fumes and gases.

Ontario Hydro has undertaken a CEA-supported project to provide a clearer understanding of welding fume-generation characteristics and potential health effects, and to identify preferred fume-control techniques for field welding operations. A document based on information generated by the project has been distributed to all field welding personnel at Ontario Hydro. This work is particularly relevant at this time as it will aid Ontario Hydro in dealing with the Designated Substance regulations recently issued in Ontario, that govern occupational exposure to welding fumes and gases.

Electric and Magnetic Fields

Standards for human exposure to electric and magnetic fields such as those produced by transmission lines and home or office appliances are currently under national and international review. The Research Division, in cooperation with the Health and Safety Division, has developed methodologies and instrumentation needed to measure workplace electric- and magnetic-field

exposures among Ontario Hydro employees, and to identify potentially unacceptable occupational exposures.

A pocket-sized magnetic field exposure monitor has been developed to determine the magnetic field exposure of switchyard workers and linemen. A microprocessor uses the signal from an internal pick-up coil to calculate one-minute averages of the magnetic field strength. Up to a week's data processed in this way can be stored in the device's internal solid-state memory and transferred from there to a personal computer for analysis.

Noise Control

Control of noise is needed in many parts of Ontario Hydro's power system and work facilities to protect staff at work and people in surrounding areas.

A field survey facility has been developed for assessing noise at generating stations. The facility monitors noise at two or more strategic locations in a station and collects weather data at the same time. This provides a reliable means of assessing noises from station activities and those from other sources. A survey using this facility was done at the Darlington construction site during the summer.

Corona discharge from transmission lines produces an audible noise during moist weather. Up to now this has not been a matter of environmental concern, but the present expansion of the 500-kV system has prompted a review of current corona noise information. Reliable measurement of corona noise has been difficult in the past because of the random occurrence of corona, the influence of weather on instrumentation, and the effects of extraneous noises. However, a system has been developed and placed in use at the 500-kV test site in Kleinburg, which automatically monitors corona noise and separates it from extraneous environmental noises. The system also collects weather data during these occurrences.

Transformer stations and their components require some form of noise control when they are close to residential areas. A special procedure was developed to isolate sources around existing

transformer stations, and thus produce more accurate data for use in developing noise control measures. Progress was made in the development of economical means for lessening the impact of noise from transformer stations on nearby residential neighbourhoods.

Electromagnetic Interference

In recent years, much work has been done to evaluate the impact on the outside world of electromagnetic interference from the power system. Research efforts have been aimed at optimizing the electromagnetic compatibility of the power system with radio navigation, communication, and radio and television broadcast services at minimum cost.

In one project, co-funded by CEA, studies were completed using a specially-built distribution test line. They provided the basis for making recommendations for modification of line design and maintenance practices in order to lessen television interference from distribution lines.

Another project was initiated which uses airborne instrumentation to gather data necessary to establish technical guidelines for maintaining the electromagnetic compatibility between power-line-carrier facilities and radio navigation and communication systems.

WASTE MANAGEMENT

Reactor Waste Management Research Program

The Research Division and the Design and Development Division – Generation have prepared a comprehensive five-year program for research in reactor waste management. The program provides a focussed strategy for research in seven main areas: waste characterization, waste conditioning, advanced waste treatment, process and equipment development, waste-form performance assessment, waste-form quality assurance, and engineered barriers.

Activities in the area of reactor waste management include storage and disposal. Specific projects include develop-

ment and optimization of a grout/concrete backfill, augered borehole field tests at the BNPD site, surface-area and pore-structure characterization of cementitious porous materials, and radionuclide diffusion studies in both saturated and unsaturated geomedias. Close contact is being maintained with US and European research institutions in the area of reactor waste geochemistry.

A fluidized grout/concrete backfill which can be pumped into normally inaccessible voids between waste packages in a reactor waste disposal facility is being developed. Two grout mixes exhibiting low viscosity, minimal phase separation and shrinkage, uniform density after hardening, and adequate durability and strength were identified as suitable. The ability of the grout mix to irreversibly adsorb gaseous CO₂ is an added benefit in that it will attenuate radiocarbon migration. Further work to evaluate water ingress, radionuclide attenuation and carbonation properties of the existing grout is in progress.

The field performance of various backfill materials placed around simulated waste packages in augered boreholes in glacial till is being tested at the BNPD site.

IAEA-Coordinated Research Program

Ontario Hydro is participating together with several research institutes, in an IAEA-coordinated research program on the evaluation of conditioned waste forms and packages. A presentation of Ontario Hydro's research on the performance of wastes solidified with water-extendible polymer and on tritiated waste conditioning was made at the IAEA review meeting in May. The research agreement has been renewed and in 1987 studies will concentrate on development of non-destructive examination procedures to determine waste form quality and establishment of quality assurance criteria.

Reactor Waste Characterization

To assist the Nuclear Materials Management Department in development of their long-range strategy for reactor-waste management, a research program



Drop tests, from a height of nine meters to an unyielding surface, were performed at AECL's Chalk River Nuclear Laboratories to demonstrate the integrity of a cask for transportation of radioactive materials. The cask was developed by Ontario Hydro's Design and Development Division.

to characterize the various waste streams with respect to physical composition, activity levels, radionuclide inventories and treatment and packaging needs for extended storage or disposal was started in 1982. Work on incinerator ash and compactable waste has been completed.

Projects undertaken in 1986 and now ongoing include the characterization of incinerable waste from the retubing of Pickering NGS Units 1 and 2, and of non-processable waste (waste consisting of items such as metallic parts not suitable for incineration or compaction). The physical and chemical composition, activity levels and radionuclide inventories of waste from normal operation and retubing at Pickering NGS have been defined.

Robotic Inspection of Closure Welds

It is planned that nuclear waste will be contained and isolated underground in metal containers. These containers will be welded shut, and a remote method of inspecting the closure welds for any defects is required. Tests are being carried out using a PUMA robot to demonstrate that a prototype titanium diffusion bond can be remotely inspected to a satisfactory level using an ultrasonic probe and waterjet. It is hoped that this demonstration will satisfy the regulatory authorities that a real closure weld can be remotely inspected.

PCB Treatment Facility

Ontario Hydro's Mobile Processing Unit (MPU) is an enclosed, trailer-



This sonic device known as "the hammer" was installed at the Rivière-des-Prairies fish bypass near Montreal to study the movement response of juvenile American shad to low-frequency, high-amplitude sound.

mounted, oil treatment facility designed to dechlorinate small concentrations of polychlorinated biphenyls (PCBs) found in contaminated electrical insulating oil. The MPU is capable of treating approximately 6000 litres of oil per eight-hour day.

The MPU made the transition from research system to commissioned treatment facility early in 1986, following a year of research testing and refinements. The design, construction, commissioning, and field operation of the MPU have taken about four years and have involved personnel from the Research Division and five other Ontario Hydro divisions. In February, a demonstration test of the MPU was carried out for the Ontario Ministry of the Environment. The test showed that the MPU could decontaminate oils initially contaminated up to 6900 mg/kg PCBs, and reduce the PCB content of the oil to <2 mg/kg, without producing hazardous emissions or byproducts.

The MPU will not be allowed to operate in Ontario until it receives approval

under the Environmental Assessment Act, but it did see commercial service in 1986 in Nova Scotia and Quebec.

AQUATIC STUDIES

Thermal Aquaculture

The Research Division is investigating the feasibility of raising the Malaysian prawn, a giant freshwater shrimp, using waste warm water from generating facilities in Ontario. These animals are currently raised commercially in several tropical areas of the world. However, they are not yet "domesticated", and hence critical knowledge needs to be gathered before mounting a production venture in Ontario.

Research is continuing to determine the influence of the conditions under which the prawns are grown on the size structure of the population. These results will be of assistance in the design of a viable commercial scheme.

Fish Control Program

A multi-disciplinary research program continued on the development of two acoustic devices for fish control, the "fishdrone" and the "hammer". Studies on the responses of several Great Lakes fish species to various frequencies and amplitudes of sound were conducted in the Research Division's unique laboratory facilities. The hammer sound deterrent was evaluated as a means to exclude fish at Pickering NGS and at British Columbia Hydro's Seton hydroelectric facility. The hammer effectively excluded the target species at both these locations, indicating the potential for using this device for fish diversion. Preliminary work to determine the feasibility of using both sound deterrents to exclude gizzard shad was done at Lambton TGS.

Studies of the effectiveness of selected behavioural systems were conducted for EPRI. The systems include light and sound devices for excluding alewife at Pickering NGS. Sound was found to show the greater promise.

JANUARY

Analytical Chemistry Robot

A new pair of hands is in training in the Analytical Services Laboratory—actually it is a single hand at the end of a manipulator arm—to carry out the repetitive steps in the preparation of samples for the analysis of PCBs in insulating oils. The robot is an integrated set of laboratory work stations, with a computer controlled manipulator moving samples through a programmed

work sequence. The robot is expected to reduce the amount of repetitive labour for technicians.

FEBRUARY

Awards Presentation

Eight individuals were recognized for their exceptional contributions and service. The W.P. Dobson Award for outstanding technical innovation was presented to Mat Cenanovic. The H.A. Smith Award for outstanding contributions that have had a major impact on

the business of the Research Division was presented to Gary Floyd and Keith Buck. Director's Awards for exceptional contributions which benefited Research Departments were presented to Mike Booth, Jerry Craig, Paul Daeschel, Al Headon and Neville Pereira.

MARCH

Transient Stability Excitation Control

A Transient Stability Excitation Control device which reduces power system instability following a major disturbance was developed and installed on all Bruce NGS and Nanticoke TGS generating units. The extra margin of safety provided by this device permits increased loading on the transmission system, with anticipated benefits of several million dollars a year. Development of this control strategy involved a collaborative effort between the Research and System Planning Divisions.

APRIL

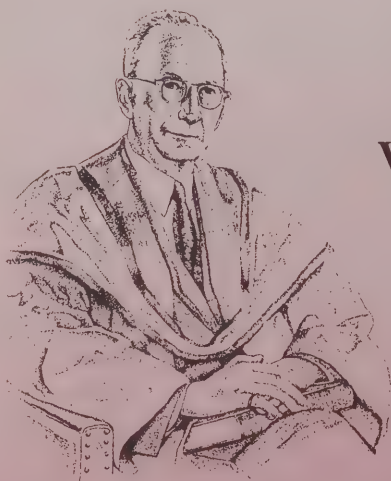
Technical Ladder

Over the past several years, the Research Division has explored the concept of a "technical ladder" for division staff. The technical ladder affords an opportunity for the Corporation to recognize the level of scientific and engineering expertise of staff members without encumbering them with unwelcome administrative responsibilities. After careful study and the establishment of selection criteria for the technical side of the ladder, the Division received approval for implementation. The appointments made in 1986 will allow staff members to devote a more appropriate portion of their time to the initiation and accomplishment of critical research.

MAY

Acid Rain

A study co-funded by the CEA is producing new and very important insight into the mechanisms of acid rain formation. Research has shown that certain cloud systems process SO_2 and deposit sulphuric acid very effectively. The findings were presented to the scientific community and have generated interest



THE W. P. DOBSON AWARD

THE H. A. SMITH AWARD



especially from Environment Canada and Ontario Ministry of the Environment representatives.

Tritium Immobilization System (TIS)

Major components of the TIS were delivered on schedule to the Darlington Tritium Removal Facility (TRF). The equipment was designed and built at Darlington Engineering by key staff from the Corrosion and Tritium Technology Section, with assistance from other divisions and from external suppliers and fabricators. The TIS equipment receives elemental tritium from the final stage of the cryogenic distillation process of the TRF. The tritium is then analyzed, assayed and reacted with U and/or Ti to form a metal tritide in getter storage beds which can be recycled or placed in long-term storage. The Research Division will provide further assistance during installation and commissioning of the TIS.

JUNE

Open House

On June 18 and 19, the Research Division hosted an open house for employees' families and friends. About 800 people toured the Division on these two evenings and viewed displays in the Chemical, Civil, Electrical, Mechanical and Metallurgical Departments.

SLAR

The preproduction tooling for the Spacer Location And Repositioning project was given a full-scale field test at Pickering NGS. This equipment includes an electromagnetic drive which was developed by Electrical Research and provides the means by which garter springs are moved by the tooling. Tests were carried out successfully with garter spring displacements exceeding easily the target displacement of 50 cm.

JULY

Welding Fume Data Sheets

Since 1980, Metallurgical Research has been studying the potential health hazards of welding-generated fumes and gases, and techniques to maintain worker exposures below acceptable lev-

els. The information was published as a booklet entitled "Fume Data Sheets for Welding and Allied Processes", by Hydro's Technical Advisory Group on Health and Safety in Welding. The booklet summarizes potential health hazards and appropriate precautionary measures for the full spectrum of welding-related processes and applications commonly used in plant maintenance and construction.

AUGUST

Plasma Material Processing

The plasma torch at the Lakeview Plasma Facility was assembled and electrically tested to 230 kW using compressed air as the plasma gas. Initially, the torch will be used to develop technology for producing chemical feedstocks via pyrolysis of coal. The availability of this higher power device will complement the low power torch at the Thermal Plasma Laboratory which was used in feasibility studies for eight industrial clients. The most recent experiments include the spheroidization of specialty metal oxide powder for one Canadian company, and reclamation of foundry sand for another.

SEPTEMBER

M-Field Dosimeter

A pocket-sized M-Field Dosimeter was developed in conjunction with Health and Safety Division to measure and record magnetic fields to which personnel are being subjected. The dosimeter stores its data in an internal solid state memory that can subsequently be interrogated by a standard data terminal.

OCTOBER

Computer Vision

Substantial improvements in productivity and quality control can be expected at a relatively modest cost through application of computer vision in areas such as the construction and maintenance in nuclear plants. Considerable promise has been shown by an initial experiment in robotic welding. A vision system provided a welding robot with sufficient sensory input to guide the

welding torch and make compensations for seam imperfections as it welds, thus leading to a reduction in weld defects and crack initiation sites.

NOVEMBER

Wood Pole Evaluation Facility

A unique test facility was completed in November to test poles up to 21m long. This facility with a maximum load capacity of 1700 kN-m breaks poles by rotating the base rather than pulling on the tip as is usually done. Testing is conducted indoors and requires a minimum of space. Load application, data acquisition and analyses and documentation of the results are automated to minimize testing time and costs and to maximize accuracy.

DECEMBER

Microwave Workshop for the Food Industry

A one and a half day workshop on microwave applications in the food industry, was held at the Research Division on December 3 and 4. Credit for the workshop's success goes to the cosponsors, Market Services and Development and Market Operations Divisions in cooperation with the Research Division and the International Microwave Power Institute. Researchers, manufacturers, and users of industrial microwave equipment shared their experiences with other potential users.

IEEE Fellowships

Congratulations are in order to two members of the Research Division, Dr. John Endrenyi (Operations Research) and Mr. Mo Kurtz (Electrical Research) on being elected Fellows of the IEEE. Endrenyi's citation reads "For contributions to the development of reliability assessment of electric power systems" and recognizes his pioneering role in power system reliability research. Kurtz's election is in recognition of his pioneering role in the development of partial discharge test techniques for rotating machines and his leadership of the partial discharge analyzer project. This technology has attracted worldwide attention and may become an international standard.

RESOURCES AND COSTS

At the end of 1986, the Division's personnel resources consisted of a total regular staff of 657. The administration and organization of staff are shown on the opposite page. The percentages of funds allocated to major work programs, the application of staff in various categories of work (Divisional Services Department excepted), and the distribution of staff in broad occupational classes, are shown below.

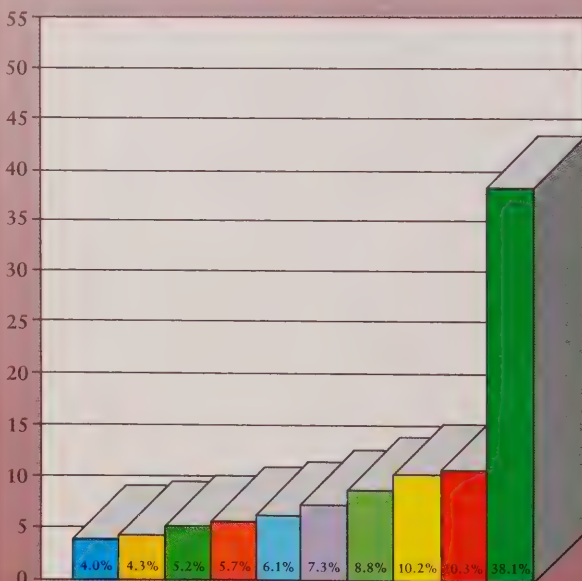
The total of all costs, including those for space, material and equipment for work done by the Research Division in 1986 was approximately \$56.6 M.

Costs were met or allocated as follows:

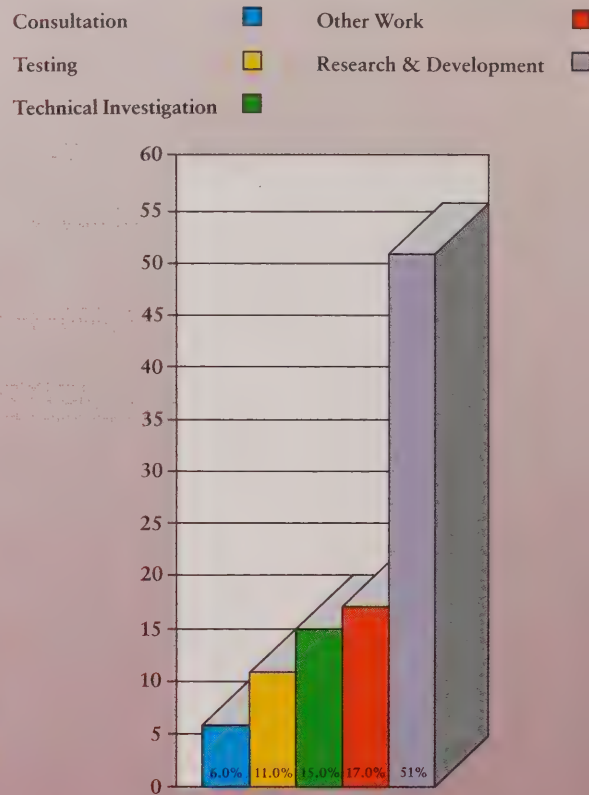
Revenue from work done for other organizations	5.5M
Transfers to other Ontario Hydro Branches	26.4M
Transfers to the Cost of Power	24.7M

Research Division Programs for 1986 - Proportions by actual gross cost

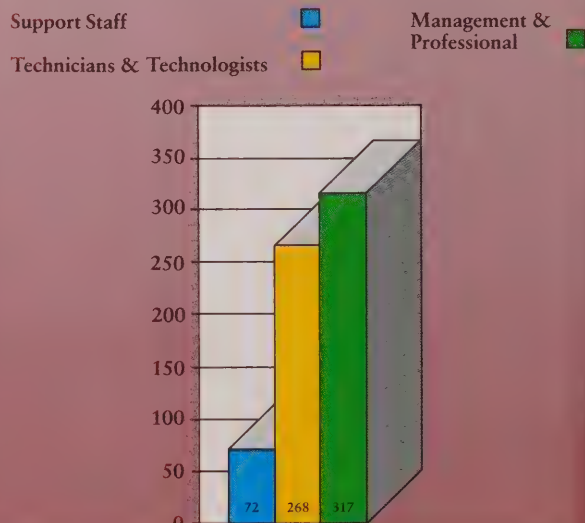
Nuclear Waste	Environmental	
Distribution System	Technical Activity	
Thermal & Hydraulic	Transmission Systems	
Electric Power Systems	General Research	
Utilization and Alternate Energy Systems	Nuclear Generation	



Proportions of total salary costs for various categories of work



Occupational classification of Research Division staff



ORGANIZATION

DIRECTOR D. Mills

ELECTRICAL A.F. Baljet

Principal Research Engineer
O. Nigol

Electrical Testing & Development
J.N. Edgar

Electronics & Instrumentation
R.D. Brown

Science
N. Anyas-Weiss

Stations & Underground
G.L. Ford

System Studies
D.C. Lee

Transmission & Special Projects
C.C. Erven

Utilization
J.M. Bell

MECHANICAL G.J. Clarke

Senior Research Engineer
D.G. Havard

Applied Mechanics
J.A. Chadha

Mechanical Testing & Development
D.B. Craig

Nuclear Process Components Test Facility
R.T. Hartlen

Plant Equipment Dynamics
T. Loewen

CHEMICAL O.A. Kupcis

Senior Research Scientist
G.L. Vascotto

Analytic Services
M.R. Booth

Biological Research
(Vacant)

Corrosion Chemistry & Decontamination Project
P. Spekkens

Environmental Science
O.T. Melo

Materials Chemistry
R.W. Glass

Process Chemistry
D.J. Dodd

METALLURGICAL J. Brown

Senior Research Engineer
M.P. Dolbey

Corrosion & Tritium Technology
P.C. Lichtenberger

Materials Integrity Project
R.G. Fleck

Metallurgy
W.H.S. Lawson

Nondestructive & Fracture Evaluation
J.A. Baron

OPERATIONS RESEARCH J.G. Cassan

Operations Research
A.H. Chung

Reliability & Statistics
J. Endrenyi

CIVIL T.W. Klym

Concrete Technology
G.S. Kellay

Concrete Control
H. Caratin

Rock Sciences
A.T. Jakubick

Soil Sciences
T.J. Carmichael

DIVISIONAL PROJECTS J.G. Cassan

Senior Research Engineer
C.J. Simpson

Research Business Relations
G.R. Floyd

Research Program
(Vacant)

Special Studies
(Vacant)

DIVISIONAL SERVICES J.B. Brown

Business Administration
G.E. Craig

Drafting
W. Zwolakowski

Editorial Services
G.R. Floyd

Information Management
C. Moraes

Model Shop
P. Stearns

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* with an organization other than Ontario Hydro

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"Radial Atomic Hydrogen Flux Measurements to the TEXTOR Liner", Seventh International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 5-9, 1986, Princeton, New Jersey.

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AECB	Atomic Energy Control Board (of Canada)	FGD	Flue Gas Desulphurization
AECL	Atomic Energy of Canada Ltd. – the crown corporation that developed the CANDU system.	GS	Generating Station – The term without a descriptive prefix is used for hydro-electric stations on the Ontario Hydro system. The oldest has been in operation since 1898.
AERE	Atomic Energy Research Establishment (of the United Kingdom Atomic Energy Agency)	IAEA	International Atomic Energy Agency
ASTM	American Society for Testing and Materials	IEEE	Institute of Electrical and Electronics Engineers
BNPD	Bruce Nuclear Power Development	LOCA	Loss-of-Coolant Accident
CANDECON	A process developed by Ontario Hydro and AECL which uses a dilute, regenerable solution to decontaminate the interior surfaces of nuclear-reactor systems.	M-Field	Magnetic field
CANDEV	CANDU Development – a program to maintain and, where practicable, improve the licenseability, safety and reliability of CANDU units in operation or under construction.	MPU	Mobile Processing Unit
CANDU	Canada Deuterium Uranium – a nuclear reactor that uses deuterium oxide (heavy water) as moderator and as heat-transport medium and natural (unenriched) uranium as fuel.	NGS	Nuclear Generating Station
CEA	Canadian Electrical Association – an association of electrical utilities that is dedicated to the development of policies and programs for the production and distribution of energy with an optional combination of environmental effects and user benefits.	PCB	Polychlorinated Biphenyls
COG	Candu Owners Group – AECL and Ontario Hydro and other electrical utilities with interests in the development and operation of CANDU units.	PHT	Primary Heat Transport
EPRI	Electrical Power Research Institute – a national organization for research and development supported by electrical utilities in the United States.	PNGS	Pickering Nuclear Generating Station
		PT	Pressure Tubes
		PUMA robot	Programmable Universal Manipulator for Assembly Robot
		REFAB	Repositioning Endfittings and Bearings
		SLAR	Spacer Location and Repositioning
		SPEL	Sheridan Park Engineering Laboratory
		TGS	Thermal Generating Station
		TS	Transformer Station



SIGNIFICANT RESEARCH CONTRIBUTION

In the mid-1970's, both Ontario Hydro and BC Hydro began examining the possibility of removing polychlorinated biphenyls (PCBs) from electrical insulating oils. These investigations resulted in the development of a chemical process which safely and effectively decontaminated insulating oils that contain low levels of PCBs. Sodium is added to heated insulating oil, and the controlled chemical reaction that results converts the PCBs to table salt and other harmless residues. The once contaminated oil may then be reused, making the process very economical.

The processing unit has been designed

and built to ensure the highest degree of safety and efficiency. Housed in a 13.7-m trailer, it can be moved to sites where the contaminated oil is stored. The unit can process up to 6000 litres of oil per eight-hour shift.

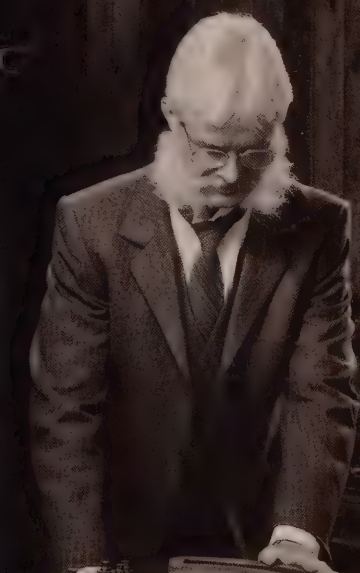
A leasing agreement with a local company for the marketing and operating of the unit across Canada will allow use of the unit in processing contaminated oils of other public utilities and private industries. In the photograph above, the unit is shown on site, at Reed TS in St. Laurent, processing insulating oil for Hydro Québec.

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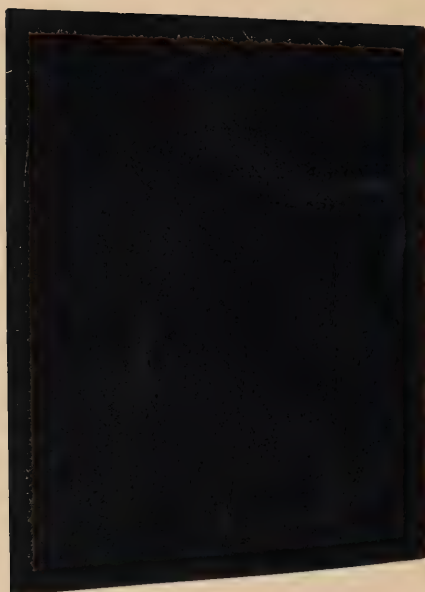
Ontario Hydro

RESEARCH ANNUAL

Government
Publications



Ontario Hydro Research Division Annual Report 1987



From its modest beginning three-quarters of a century ago, the Research Division has grown to be a vital part of Ontario Hydro. Not satisfied with just peering through windows, Hydro researchers have, since 1912, continually endeavoured to make Ontario Hydro a world leader in electric utility research.

The front cover shows a scene from an early standards laboratory, such as was set up by Ontario Hydro circa 1916. The view through the window contrasts the precision instruments of this era with the technology of the 1980s used by Hydro in support of its nuclear generation.

A selection of significant research contributions made during the past seventy-five years is shown on the inside back cover. As always, Ontario Hydro strives for excellence in service to its customers through the talents and commitment of its people and the wise use of modern technology and practices.

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Nineteen eighty-seven marked the 75th Anniversary of the inception of laboratory research at Ontario Hydro. This makes Ontario Hydro's Research Division the oldest utility research organization in North America. The Research Division has, over the years, established a world wide reputation for innovation and leadership in electric utility research.

Throughout its history, the Division has developed many new techniques and instruments that have been adopted by others. For example, the Soniscope, an instrument developed in the 1950s to inspect large concrete masses by means of ultrasonics, is being used around the world. The Soniscope is not the only development, and a brief description of the Research Division's history of accomplishment is given in the supplement at the back of this year's report.

Ontario Hydro has always been concerned with helping its customers to make good use of electricity. In fact, right from its beginnings, the Research Division was involved in testing and evaluating electrical products and setting standards for their manufacture and application. As well, Ontario's manufacturers have used information generated by Hydro's research to improve the quality and competitiveness of their products.

I congratulate the management and staff of the Research Division on the completion of seventy-five years of outstanding contributions to Ontario Hydro and to the power consumers of Ontario.



L.G. McConnell
Vice-President
Power System Program



Lorne McConnell holds a klydonograph, a device developed at the Research Division to record lightning-produced voltage surges on transmission lines.

This year marked the seventy-fifth that research and development has been an integral part of the Corporation's work program. Throughout its history, the Division has been responsible for meeting Ontario Hydro's current technological needs. In recent years, because of rapid technological growth and change, increased emphasis has been placed on anticipating the Corporation's future technical requirements.

Coupled with increased pressure to keep pace with scientific advances is the need for new technologies to deal with social and economic concerns. For example, current interest in environmental issues has resulted in

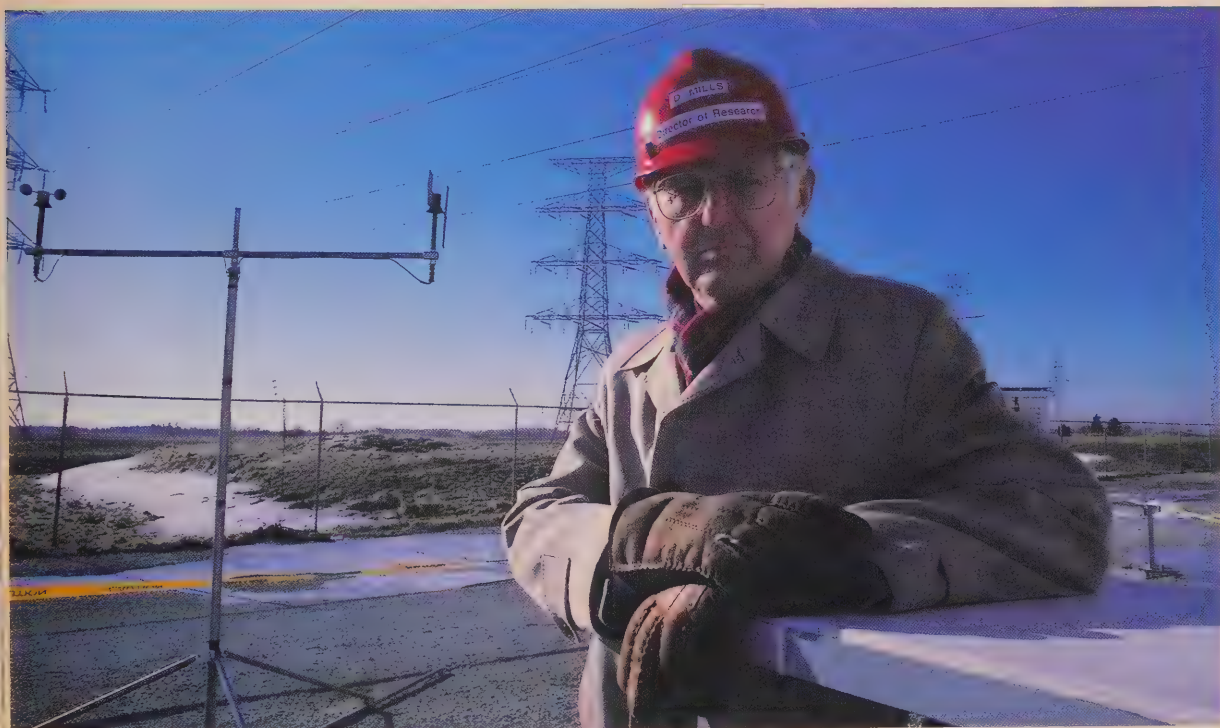
a concomitant increase in related research activity. Although the Corporation has always tried to minimize the impact of its operations on the environment, more information about the effects of power system operation on the environment and better methods to mitigate these impacts are required. The Division's current work includes such activities as the investigation of options for controlling acid-gas emissions; research into the transport, transformation, and deposition of pollutants; and novel concepts of vegetation control in transmission corridors. The Division has also achieved world recognition for its use of behavioural

techniques to minimize the impingement of fish at generating stations.

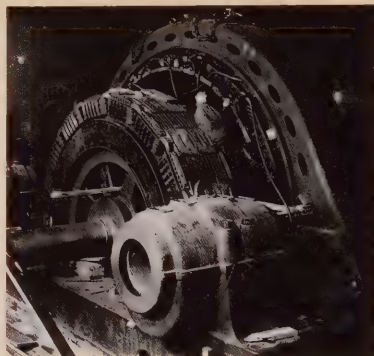
Environmental research is of course only one of the Division's ten programs. As in the past, Research staff are today providing technical support for the Corporation which will help ensure a reliable and inexpensive supply of electricity in the future.



Don Mills
Director
Research Division



Don Mills visits an environmental monitoring installation at Trafalgar TS.



Inspection of generator No. 2 at Ontario Power Generating Station in 1905.

Manager's Report

The Chemical Research Department has approximately 70 scientists and engineers and an equal number of technical and support staff who work mainly in the chemical, biological, and environmental disciplines. The Department's research and development program in support of the Corporation's needs is comprehensive, ranging from long-term scientific investigations and short-term problem-solving, to provision of chemical analytic services.

In 1987, research in the nuclear and environmental areas constituted the largest components of the Department's work, each area representing approximately one-third of the total \$12 million dollar program.

In the nuclear area, numerous projects were carried out in materials development, reactor component

integrity, and in chemical process development, which contributed to the continued reliable and safe operation of Ontario Hydro's CANDU reactors and to the repair and maintenance activities associated with reactor retubing.

In the environmental field, major efforts continued in developing methods for controlling acid-gas emissions from coal-fired stations and in establishing their environmental pathways. Biological surveys were carried out to determine the impact of Ontario Hydro's generating facilities on the environment.

A number of long-term programs saw commercial application this year. The development, in conjunction with CFFTP, of a chromatographic system for separating hydrogen isotopes for fusion facilities was completed, and the system was sold to the Karlsruhe

Tritium Laboratory in West Germany.

The process for polychlorinated biphenyl (PCB) destruction, which was developed jointly by the department and BC Hydro and licensed to an Ontario-based company, operated successfully both outside the province and within Ontario Hydro to decontaminate 150,000 litres of PCB-contaminated oil. An acoustical device for controlling fish movement at intake structures successfully proved its effectiveness at various locations, and negotiations are currently underway to transfer this technology.

The Chemical Department is divided into five sections with responsibilities in the areas of process chemistry, materials, analytic chemistry, biology, and environmental science. In addition, the Department has a project group working in the area of corrosion chemistry. The Department also has

CHEMICAL

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Dr. O.A. Kupcis

Senior Research Scientists
Dr. G.L. Vascotto
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Biological Research
Dr. A. McMillan

Corrosion Chemistry &
Decontamination Project
Dr. P. Spekkens

Environmental Science
Mr. O.T. Melo

Materials Chemistry
Dr. R.W. Glass

Process Chemistry
Mr. D.J. Dodd



Extracts of water samples are being prepared for analysis on a gas chromatograph/mass spectrometer that can detect and identify trace quantities of organic compounds in environmental samples. The technician is shown taking a small sub-sample for subsequent injection into the instrument.

two senior research scientists who are involved in projects on prawn aquaculture, on the biological effects of electromagnetic fields, and on the quality assurance of radioactive waste forms.

Technology is being developed for the thermal aquaculture of giant freshwater prawn. The successful demonstration of this technology is expected to create a significant market for waste heat and steam, and in some cases, electricity. Substantial progress towards this goal was made in 1987. The objective in 1988 is to firmly establish commercial interest in this technology.

Since the 1980s, public concern about the possible health effects of electromagnetic fields has increased. As part of a broad Corporate program to address this issue, a study has been proposed to test the hypothesis that exposure to 60-Hz fields may increase the activity of carcinogens.

The management of operating wastes from Ontario Hydro's nuclear reactors requires that packages of radioactive waste have acceptable integrity and no flaws. The development of methods for assessing the quality assurance of radioactive waste forms was started in 1987 and constitutes Ontario Hydro's component of an effort coordinated by the International Atomic Energy Agency (IAEA).

Analytic Services

The Analytic Services Section supports the research of scientists across the division by providing advice, state-of-the-art instrumentation, and chemical analytic services. Scientists consult with analysts to work out the best experimental designs to ensure that chemical analysis of samples will provide them with optimal data. Analysts maintain the existing analytic capability of the laboratory and develop new techniques to meet special requirements. Essentially, the Section functions as a central service laboratory for the Corporation.

Significant changes in the regulatory environment during the past year affected the requirement for chemical analysis. Application of the "Transportation of Dangerous Goods Act", increased concerns associated with handling of hazardous materials, constraints on temporary storage and disposal of industrial materials, and the Municipal-Industrial Strategy for Abatement (MISA) all increased the need for chemical analysis. During the

year, the analysis of PCBs in transformer oils was fully automated. Robotics allowed the handling of increasing volumes of "rush" analyses. Dual-column capillary gas chromatography was developed to relieve the pressure of handling large numbers of gas chromatography and mass spectrometry analyses. A complete screening of effluents from all power plants was carried out under MISA protocols to develop the required materials handling and the analytical protocols for the regulation development phase, which is scheduled to occur in 1988.

Laboratory capabilities were enhanced in the areas of gas chromatography, liquid scintillation counting, and x-ray fluorescence. The labour-intensive analysis of gases in transformer oils, used to identify transformers likely to fail, has been fully automated. A new analyzer allows carbon in water to be analyzed at levels of interest to thermal power plant operators.

The carbon-14-containing solid from the annulus of Pickering NGS Units 1 and 2 was studied in detail. It has not yet been possible to define a particular molecular structure for the material, but the best evidence available shows it to be a carbon-nitrogen-oxygen polymer. Studies were carried out on the oxidation of the carbon-14 to determine if it could be gasified by heat and oxygen. These studies are ongoing.

Biological Research

In 1987, the Biological Research Section continued to contribute to the Corporate program to assess biota around generating stations. Components of the program included field surveys, vegetation studies for right-of-way management, radionuclide studies, and work in behavioural fish control systems.

The goal of the vegetation control program is to identify more effective and more environmentally responsible means of controlling undesirable vegetation on transmission and distribution rights-of-way. Past studies have



Experimental acoustic devices were installed at the Annapolis Tidal GS in Nova Scotia (top) and New York State (bottom). These devices are being evaluated as a state-of-the-art method to exclude fish from the water intakes of generating stations.

explored novel concepts of vegetation control, attempted to improve on existing control techniques, provided environmental information, and evaluated new products. The effects of tree cutting, population dynamics of the right-of-way vegetation, and the investigation of trunk injection of growth regulators were the main areas of investigation this year.

The radionuclide program focuses on determining the biological behaviour of tritium and other radionuclides produced by Ontario Hydro's nuclear facilities. This year, our investigations focused on deuterated materials, tritium and biofouling.

Site observations continue to enable

the environmental effects of the construction and the operation of generating stations to be determined. For example:

- a) At Nanticoke TGS, an investigation of the biological consequences of the elimination of tempering of discharged cooling water was carried out. In addition, a summary of the influence of industrialization on the aquatic environment around Nanticoke was prepared.
- b) At Bruce NGS, a year-one post-operational study focused on small-mouth bass reproduction and recruitment. Investigations of round whitefish spawning continued.
- c) The effects of the Big Chute hydraulic development are being

assessed at Six Mile Lake, and modelling is being undertaken to determine whether changes in the direction and volume of inflow will affect the habitats of fisheries.

d) Water quality, fish spawning habitats, and fish species distributed below Red Rock GS, were monitored to determine the effect of bank stabilization on the aquatic environment.

Environmental Science

The Section continues to investigate a number of options for controlling acid-gas emissions. The calcination and sulphation reactions of Ontario limestones were studied under simulated furnace injection conditions.



This laser probe is part of the instrumentation package used to investigate the meteorological, microphysical, and chemical properties of freezing precipitation and fog in Southern Ontario. Results from this study are expected to lead to a better understanding of such weather and to identify areas for further study as part of a program to solve a 500-kV insulator icing problem.

Experimental facilities were built to study incremental sulphur dioxide capture in the ductwork of power plants that use dry sorbent injection with humidification. Similarly, filter deposits of power plants equipped with baghouses were investigated. A preliminary study of simultaneous sulphur dioxide and nitric-oxide control using transition metal catalysts was completed.

Three other projects initiated in previous years were completed. One of these was an international study of the environmental pathways for elemental tritium. The controlled release and monitoring of tritium at two field sites, one in Canada and the other in France were involved. Results demonstrated that the oxidation of elemental tritium to the more radiotoxic tritiated water vapour occurs only slowly.

Two other projects dealt with environmental pathways of acid gases. In one, the transport, transformation, and deposition of pollutants by clouds were studied by means of mathematical models. The models predicted that some clouds effectively transport pollutants vertically in the atmosphere. In addition, cloud processes were predicted to result in nonlinear relationships between air pollutant concentrations and acid deposition.

In the other project, the dry deposition of sulphur and nitrogen dioxides to a number of surfaces was measured. It was found that deposition rates to snow covered surfaces are very slow, and that nitrogen dioxide fluxes over vegetation need not be down to the surface, thereby indicating that the snow's surface can be both a source and an absorber of nitrogen dioxide. Results from these projects suggest that long-range transport models need improvement.

The licensing of nuclear stations and the design of safety equipment requires knowledge of the amount and the properties of radioactive aerosols that could be generated in the unlikely event of an accident. A capability to generate and to study aerosols was partially developed this year and was used to study the formation of liquid aerosols under simulated nuclear accident conditions.

The Section continues to support the Provincial and Corporate nuclear emergency preparedness program by providing expert advice in atmospheric dispersion and meteorological monitoring.

Expertise in the atmospheric sciences was applied to a problem of great current concern: the icing, wetting, and contamination of insulators. An instrumented field station was set up to measure the chemical and physical properties of storms involving freezing rain in Ontario. In addition, a laboratory study of insulator icing and wetting by the fog accretion mechanism was initiated in collaboration with a Canadian University.

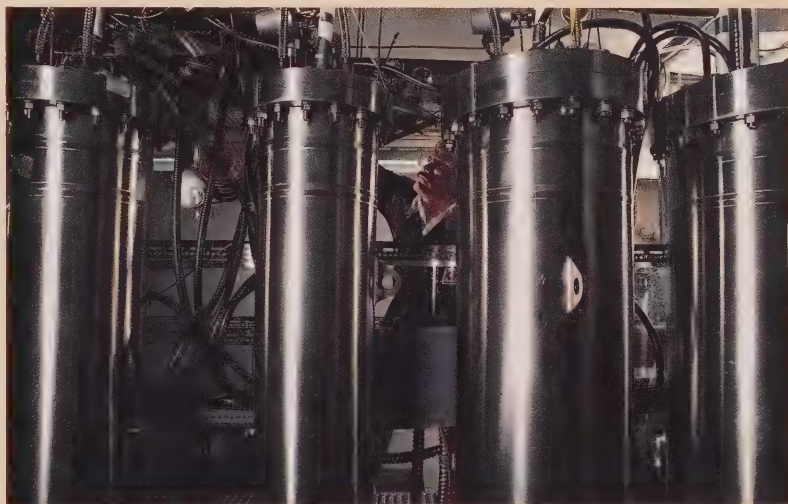
Materials Chemistry

Nuclear containment integrity activities involved a major inspection of the condition of non-metallic materials in the Bruce NGS 'A' vacuum building. Development of techniques to detect and quantify containment building leakage continues and a tracer gas method that uses ethylene was used

(GIS) and liquid dielectric transformers demonstrated that moisture migration, generation, and content reduced equipment performance. Moisture is present in solid insulation such as epoxy resin spacers, paper and press-board. The moisture is formed from material degradation under overload conditions. A computer program, MOISTGIS, has been developed to assess moisture content and distribution as it relates to GIS. The effect of moisture, temperature, oxygen, and gassing on by-product formation is being studied to establish power transformer acceptance criteria.

Several deuterated materials were synthesized and their performance fully characterized as part of a program to assess the potential for wider use of these materials.

Research to define immobilization and packaging requirements to allow



A gas chromatographic hydrogen isotope system has been sold to the Karlsruhe Tritium Laboratory in the Federal Republic of Germany. The technology has been transferred to Labserco Limited in Oakville, Ontario.

successfully during a four unit outage at Bruce NGS 'A'.

The occurrence of pressure relief duct seal failures during the commissioning of Pickering NGS 'B' initiated studies on the aging characteristics and performance of elastomeric seals. When examined, these seals, which had been in service for up to 17 years, revealed only slight changes in hardness and little oxidative degradation. Most deterioration appeared to be attributable to mechanical damage.

Research into the deficiencies of materials in gas-insulated switchgear

storage and eventual disposal of tritiated waste with acceptably low environmental releases was completed. A full-scale, prototype liquid waste immobilization system for use with water-extendible polyester resin as the solidification matrix was demonstrated to Design and Development and Nuclear Operations personnel.

Process Chemistry

The Process Chemistry Section seeks to provide effective and cost-efficient technology for treating liquid and gaseous streams in generating stations. For Hydro's nuclear stations, studies

are underway to develop highly selective sorbent materials for purifying water in the primary heat transport system, moderator and irradiated fuel bays. Static batch equilibrium tests and some preliminary column screening tests have already been performed.

The development in the laboratory of a gas chromatography system for hydrogen isotope separation allowed a commercially-scaled demonstration system to be designed, assembled, and tested. The work was funded by Karlsruhe Tritium Laboratory in West Germany, and the Canadian Fusion Fuel Technology project (CFFTP).

A patent based on the pilot-scale development of this system has already been granted in the United States. In addition, the commercially-scaled system, designed and assembled in cooperation with a Canadian company, is part of a technology transfer effort to involve a private company at

The study aims to quantify SO_2 capture, sorbent utilization, waste characteristics, and electrostatic precipitator performance. Work to enhance SO_2 capture and restore electrostatic precipitator performance through humidification has been completed. Overall SO_2 capture by this two-step process is approximately 63 percent.

To facilitate safe handling and disposal of the solid waste that results from limestone and lime injection into furnaces, detailed chemical and physical characterizations of solid waste have been made. The fixated wastes were found to resemble fly ash and certain earth materials, and being "non-leachate toxic", suitable for use as landfill or backfill.

The development of an electrochemical pilot plant and test facility for the synthesis of ethylene glycol came closer to completion. The design of a

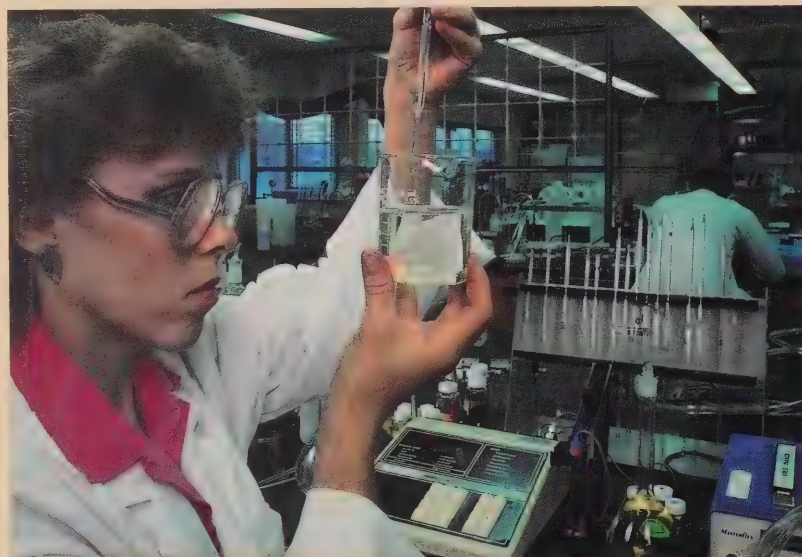
nuclear plants. To date, CANDU reactors lead the world in steam generator integrity. However, a long-term research program is in progress to anticipate problems that may occur and to develop remedial measures to avoid or minimize their consequences.

The greatest risk to Ontario Hydro's steam generators is the formation of chemically aggressive conditions under sludge, which accumulates both on the secondary face of the tubesheet and in the crevices at the support plates. The rate at which these contaminants concentrate has been studied in laboratory autoclaves and a model has been produced to describe the process. Further study is aimed at determining the nature and severity of corrosion under sludge deposits. Last year, emphasis was mainly on Incoloy 800 tube material, which will be used at Darlington NGS.

The removal of accumulated deposits in steam generators may be required if under-deposit corrosion threatens the integrity of materials or if fouling of heat transfer surfaces results in power output reductions. A multi-year program to develop solvents capable of chemically removing these deposits was completed.

The most effective means of avoiding under-deposit corrosion is to minimize its formation. Deposits are formed mainly from the low levels of impurities produced by corrosion of the secondary system pipework. Deposits gain entry to the steam generator via the feedwater. Thus, as part of a long-term project to identify and, ultimately, to control the sources of these impurities, sampling equipment has been installed in a Bruce NGS 'B' unit.

The group was also active in decontamination studies in 1987. A major requirement of the CAN-DECON chemical decontamination process continues to be the development of a sulphur-free inhibitor. Detailed laboratory evaluations of three candidate inhibitors were continued this year through a collaborative effort by researchers at the Division, at the AECL-Chalk River Nuclear Facility, and at the University of Guelph. The scope of the Guelph study is being expanded by means of a grant from the Natural Sciences and Engineering Research Council. Investigations of the fundamental mechanisms of corrosion inhibition at carbon steel surfaces under decontamination chemistry conditions are being carried out.



In the Process Chemistry Laboratory, a leachate extraction test is being performed as one of the many tests conducted to characterize wastes produced by the various acid-gas control processes under investigation.

a developmental stage of the project. Following successful testing in the demonstration system, an engineering design of equipment for hydrogen isotope separation at the Karlsruhe Tritium laboratory was provided.

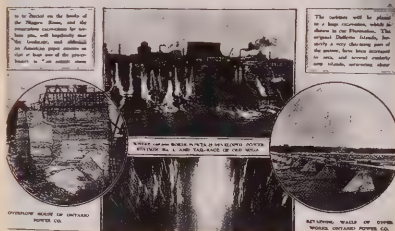
Sulphur capture by in-furnace injection of calcium-based sorbents has been studied under conditions simulating full-scale operation at Ontario Hydro's 640-MJ-per-hour Combustion Research Facility. These studies are a significant component of the Corporation's acid-gas control program.

12-kg-per-hour electrochemical pilot plant has been completed. The design was complicated not by the chemistry, but rather by the need to contain and safely dispose of chemicals and electrolytes in the product stream.

Corrosion Chemistry Decontamination Project

Degradation of steam generator tubes, which may result in primary coolant leaks, is a major concern in

THE WORLD'S GREATEST WATERFALL RUINED TO SUPPLY ELECTRICITY.



Views on power development at Niagara Falls as featured in the London Illustrated News in 1906.

Manager's Report

The Research Division's 75th Anniversary year has been a challenging one for the Civil Research Department. The continuing construction of the Darlington nuclear generating facility, rated as one of the world's mega projects, gave the Department numerous opportunities

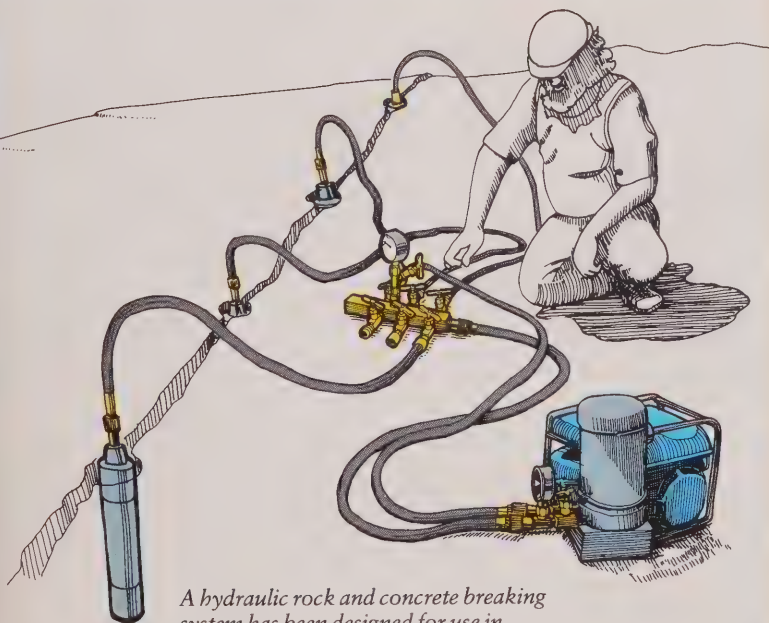
to utilize its expertise in such specialty areas as advanced concrete technology and geotechnical engineering.

Nuclear Generation Division called upon the Department to assist in testing and monitoring their nuclear containment structures, and currently, reactor and vacuum buildings are being tested at the Pickering and the

Bruce facilities to ensure their continued safety and reliability.

Ontario Hydro's large commitment to nuclear energy makes studies related to the safe and environmentally acceptable storage, transportation, and ultimate disposal of irradiated nuclear fuel a high priority. Thus, concentrated effort has been made by the Department to cooperate with the Design and Development Division of Ontario Hydro and with Atomic Energy of Canada Limited, both of which are involved in these types of studies.

In addition to our commitment to ensuring the safe and reliable operation of Ontario Hydro's important nuclear structures, a concomitant concern is reflected in Civil Research's effort to ensure the optimal performance of Ontario Hydro's hydraulic generating facilities. This year, the Department has played a significant role in the Dam Safety Program. The work involved site investigations, through the preparation of design



A hydraulic rock and concrete breaking system has been designed for use in areas where blasting techniques cannot be safely used, such as near structures, sensitive equipment, and in residential areas. The rapid, portable system can be pressurized from a safe distance with the aid of a hydraulic pump and high pressure hoses.

CIVIL
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reviews, to rehabilitation and performance monitoring. These efforts have led to the Department's participation in remedial work on a number of facilities. Work was carried out at Crystal Falls GS, Bray Lake GS, and at DeCew Falls GS. In addition, rehabilitation work was done on the Cedars Channels and Waba Dams.

Another Corporate priority is minimizing the impact on the environment of a number of power generation operations. The Department has thus given increased attention to wastes generated from thermal plants; work was done in the areas of acid flue gas control, fly ash management, and in the disposal of flue gas desulphurization wastes. Similarly, considerable effort has been devoted to developing controls on wastes generated from nuclear power facilities. Two such controls



As part of the corporate Dam Safety Program, researchers installed pendulums and precise surveying stations to measure the deformation of the Pine Portage concrete dam.

currently under study involve radioactive carbon emissions and the disposal of reactor and irradiated nuclear fuel wastes, the latter being of great environmental concern.

Soil Sciences

In the area of thermal plant waste management, the Soil Sciences Section continues its involvement in specialized geotechnical and hydrogeological research and consulting. To provide input into the management of coal ash produced by coal-fired stations,

laboratory and field projects were conducted to investigate the movement of contaminants beneath the coal ash lagoon at Nanticoke TGS and to provide design values for the analysis of the stability of the long-term ash storage mound. In addition, innovative utilization options for the ash produced at the Lakeview and Nanticoke TGS facilities were investigated.

Numerical modelling and full-scale transmission tower foundation testing led to design innovations in the new narrow-based 500-kV transmission towers. Participation in transmission tower refurbishment studies included the evaluation of the condition and load carrying capacity of foundations of transmission lines constructed more than 30 years ago. These studies are expected to provide a greater insight into the life expectancy and reliability of old lines.

With regard to technology transfer, a training seminar was conducted by section staff for Chinese engineers in Beijing; the subject of the seminar was the "Theoretical Analysis and Practical Applications of Transmission Tower Foundations". The seminar was presented to engineers from the Electric Power Construction Research Institute and was funded by the Canadian International Development Agency.

Soil Sciences continued to support research and development efforts in medium- and high-level radioactive waste disposal studies. Through Ontario Hydro's Technical Assistance Program, which supports the AECL / WNRE Waste Management Program, studies are ongoing in the near-field heat and moisture modelling experiment for the reference design of underground disposal of irradiated fuel wastes. Ontario Hydro's technical expertise in thermal modelling, grouting, and backfilling was sought by AECL / WNRE for their Underground Research Laboratory experiments which are being carried out near Pinawa, Manitoba.

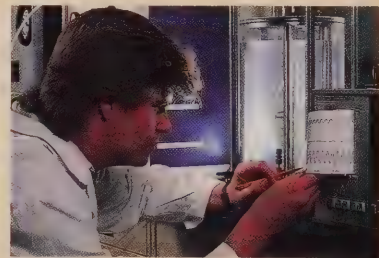
The Section plays a significant role in soil thermal measurements and in the theoretical modelling of heat and moisture as related to underground power cables, ground source heat pump performance and underground nuclear waste disposal. This expertise has been marketed to outside utilities through Ontario Hydro's New Business Ventures Division.

As part of a 7-year performance review of the Corporation's concrete and earth water-retaining structures,

the Dam Safety Program was provided with consultation services and reviews of historical data. In addition, state-of-the-art technology was applied to investigations of the DeCew Falls GS dykes and the Arnprior GS Waba Dam to provide parameters for inclusion in dam stability reviews. Instrumentation was installed at Pine Portage GS and other dam structures in support of the Thermal and Hydraulic Generation Division's long-term performance monitoring programs.

Rock Sciences

Rock Sciences is participating in a multi-agency effort (the Integrated Stress / Neotectonics Study for Seismic Hazard Assessment) to improve current capability to assess site-specific seismic hazards with low levels of probability of occurrence. The aim



A dynamic triaxial test is being performed on soil taken from one of Ontario Hydro's dams to determine the resistance of the soil to earthquake-type loading.

of the project, which involves such agencies as the Geological Survey of Canada, the Atomic Energy Control Board, the Ontario Geological Survey, the Ontario Centre for Remote Sensing, Laval University, the New Brunswick Department of Natural Resources, and the University of New Brunswick, is to allow application of more stringent criteria to critical structures than those now required by the National Building Code of Canada.

In 1987, research was directed at determination of the three-dimensional stress field in a rock mass and the integration of the observed neotectonic data with this field on an outcrop scale. Several field sites were involved. In southern Ontario, the integrated geo-scientific approach was tested at a research site (the Robindale quarry) near Napanee, where ground probing radar revealed evidence of geologically recent movements. Memorial University in Newfoundland and Queen's

University in Ontario are carrying out a hydraulic pumping study to test the effect of hydrogeological changes on seismic activity.

Concrete Technology

The past year was a challenging one for the Concrete Technology Section. Projects were designed to address both the Corporation's current and anticipated needs.

In order to facilitate access through swamps, muskeg, and lakes, most transmission line construction must be performed during the winter months. Thus, since cement-based concretes and grouts require costly protection from the environment during the early stages of curing, a need arose to develop materials that were not adversely affected by subfreezing temperatures. A polymer concrete suitable for use at temperatures down to minus 25°C without the need for protection was developed, and substantial savings in the cost of tower-footing construction were realized. In northern Ontario, the development of this novel material has facilitated cost-efficient construction

of a major guyed extra-high-voltage transmission line under severe winter weather conditions.

An on-going concern in structure maintenance is the selection and use of repair materials. A rehabilitation and repair program was undertaken to assess the use of both organic and inorganic materials in hydraulic, thermal, and nuclear structures. Considerable work has been done to identify the physical characteristics of candidate materials, and their long-term performance is currently being evaluated.

In 1987, a four-year study on the behaviour of reinforced concrete structures subjected to thermal gradients was completed. The program involved the construction of models and their monitoring during tests. The result was the formulation of analytical methods to predict behaviour. A computer program to analyze structures subjected to thermal and mechanical loads was developed, thus enabling designers to predict more accurately the consequences of thermal stresses.

Concrete casks are being considered for storage of irradiated fuel. However, the development of these casks

requires costly testing of prototypes. It is therefore necessary to test scaled-down versions. A major difficulty with scaling-down is the determination of the scaling effect on observed results. Thus, a program was undertaken to investigate size-effect on specimens subjected to a drop test. Four models of varying size were instrumented and tested to determine their response to impact loads. The data from this study will help in predicting the behaviour of a full-scale prototype.

Concrete Control

The Concrete Control Section has inspected and tested approximately 70,000 m³ of concrete placed at the Darlington NGS construction site. A crew of 12 inspectors sampled cement, aggregates, and concrete to check for conformance with rigid project specifications.

In addition, inspection was provided during the rehabilitation of the Cedars North Channel Dam, Eugenia GS, and the Ontario Power Generating Station's intake structure and screenhouse.



Laboratory concrete specimens, stored in controlled temperature and humidity environments, are regularly monitored as part of a practice to ensure the quality of materials used in Ontario Hydro's structures. In addition, an evaluation of the effectiveness of corrective measures is made in cases where the use of problem materials cannot be avoided.

Manager's Report

The Divisional Projects Department interfaces with various groups within the Division, within Hydro as a whole, and with other groups external to the Corporation. Its activities may be subdivided into Special Studies, Research Management Studies, and Research Business Support.

In the category of Special Studies, the Department carries out liaison and coordinating functions, both within and external to Ontario Hydro to identify new areas of research and, where appropriate, to initiate projects. Advice and resources are drawn from the Research Division and other Hydro Divisions, from industry, universities, and government agencies.

In 1987, emphasis was on increased Research Division participation in the development of new electrotechnologies of benefit to Ontario industry. Work continued on the coordination of plasma arc and advanced ceramic programs. Cooperation with the Metallurgical Research Department and the Marketing Branch resulted in a plan for the establishment of an

DIVISIONAL PROJECTS

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A scene from the parade that preceded the formal inauguration of electric power service in Berlin (now Kitchener) in 1910.

electric furnace facility for use in cooperative research and development on ferrous and non-ferrous metals.

Work began on an industrial laser program. Links to the laser community were strengthened by the appointment of a member of the Division to the position of adjunct professor in the Laser Applications Laboratory at York University and to the User Facility Committee in the Centre of Excellence in Laser and Lightwave Research at the University of Toronto. Industrial partners for a collaborative program of research and development of ceramic powder production technology have been identified and proposals for funding are being developed.

Production of technological forecasts is ongoing. This year a Delphi study, focused on advanced industrial materials, was carried out in conjunction with the Operations Research Department. Addressed were the areas of ceramics, plastics, metals, and electrolytic and superconducting materials. The study was directed at Marketing and Research personnel. A paper on technology forecasting was co-authored with Operations Research personnel, and this will be presented at the International Conference on Technology Management in February, 1988.

Artificial Intelligence (AI) is an important area of inquiry. Regular issues of the AI newsletter continue to be a valuable tool for communication within Hydro's AI community. A computer program was developed which incorporates some of the expertise of a senior meteorologist and will assist in forecasting conditions likely to produce icing on transmission lines. A small neural network simulation was designed to investigate the speed with which the network can be taught to distinguish between simple shapes.

The Department provides external contracts support. A guide for the production of research contract proposals, a general confidentiality agreement, and intellectual property clauses for external consultants were some items developed during 1987.

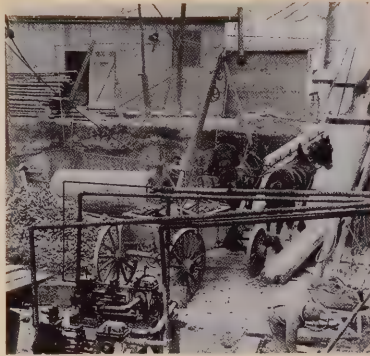
This year was the Research Divisions's 75th Anniversary and the Department took the lead role in planning and organizing celebrations. An anniversary logo was commissioned and has found a number of applications. A video that traces the history and the accomplishments of the Division was produced, and this was first screened during the Anniversary Open House in June. Over 1,500 people visited the Division during this 3-day event. In October, a symposium on the "Value of Research to Society" was hosted by the Division at a local hotel. Guest speakers from other organizations with an interest in research presented papers describing the significant role research plays in supporting modern society.

The Division has many visitors. This year, the Department organized over thirty tours. Among the visitors were delegations from the Lawrence Berkeley Laboratory and from various foreign utilities and research organizations. University students from local and foreign institutions and members of Hydro's own training program also participated in many tours.

Posters promoting the achievements of the Division were produced to encourage students to consider careers in science or engineering. In addition, the Department participated in the celebration of the 100th Anniversary of the Association of Professional Engineers of Ontario. A display was produced and sent to various locations in the province.



To further assist Ontario industries, researchers are studying the cutting, welding, and drilling of various materials with an industrial carbon-dioxide laser.



Construction of Hydro's first Head Office Building at 610 University Avenue in May of 1915.

Manager's Report

The Electrical Research Department's research and development program is extensively interactive with other Divisions in Ontario Hydro and, where appropriate, with industry and the public. The objective of the overall program is to serve the present and future needs of both the Corporation and Ontario's Municipal Utilities and to work together with Canadian Industry in an effort to introduce energy saving electrotechnologies in manufacturing.

Research studies of benefit to Ontario Hydro and its customers are also carried out under contract to organizations such as the Canadian

Electrical Association and the Electric Power Research Institute in the United States. It is of interest to note that the general trend in utility research towards near-term development projects and generic problem solving was also evident in the overall Electrical Research R&D program in 1987. While several long-term studies continued, primarily in advanced diagnostics, artificial intelligence, and high-power laser applications, a number of high-priority near-term objectives were pursued in close cooperation with other Divisions. Two programs which are unique to Ontario Hydro, deserve special mention. The first concerns the reliable performance of 500-kV power transmission facilities during atmospheric conditions such as freezing rain, dense fog and near-freezing temperatures. The second aims at increasing generation limits for major power plants operating under severe transmission constraints. Both of these in-house research programs have attracted international attention and could well lead to new utility practices.

To alleviate the consequences of increasing limitations on the construction and operation of power lines, an in-depth design optimization program is underway that takes into account considerations of terrain, environment, material properties, and alternative design techniques. The program also addresses optimum utilization of existing transmission lines. Initial results of the above studies were part of the content of a ten-day seminar presented in China under the auspices of the Canadian International Development Agency.

A new CSA Standard (C-233.1), Gapless Metal-Oxide Surge Arresters for Alternating Current Systems, which has been in preparation for five years, has reached the stage of publication. This document is the

most complete standard on the new metal-oxide surge arresters and will meet the needs of Canadian power utilities for years to come.

A defacto standard in hydraulic generator maintenance was established in 1987 with the completion of an agreement with a Canadian company to manufacture and market world-wide, a new diagnostic instrument for on-line insulation quality monitoring. This instrument is one of a group of electronic devices both developed and still under development for use in the power system. Many of these devices will ultimately be integrated in a "Power System Integrity Control" system, now in the early stage of development.

Several initiatives were taken in support of distribution system maintenance and customer equipment performance. Consultations with the Municipal Electrical Association resulted in a decision to direct these activities more formally in the best interest of Ontario's Municipal Utilities.

A summary of the research and development effort in the Electrical Research Department follows.

Transmission & Special Projects

A major concern this year was the occurrence of multiple flashovers of 500-kV line suspension and station post insulators during atmospheric conditions marked by light freezing rain, followed by fog and rising temperatures. Because of limited transmission facilities from nuclear generating stations, the determination of cause and the need to find a remedy for the flashover problem became critical. Thus, in cooperation with Region staff, and Production, Power System Program and Design and Construction Branches, an extensive laboratory and field testing program has been put in

ELECTRICAL

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Utilization
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Electromagnetic interference measurements were taken for the Toronto Transit Commission to verify that their H6 subway car complies with commission specifications. Normal subway operation was suspended while these tests were performed in the early morning hours at an open section of track near the Kipling subway station.

place to assess the performance of available insulator arrangements and to evaluate new designs based on an understanding of the flashover mechanism.

Load loss due to the high failure rates of some low-voltage station bus support insulators led to field tests that resulted in the development of a positive puncture detector for field use. Another new development was a prototype grounding stick to protect cargo handlers from exposure to hazardous electric shocks caused by electrostatic charging of hovering helicopters. This device was successfully developed and tested during repairs to the top of a Nanticoke TGS stack.

Contributions continue to be made at both a national and an international scale to the development of better performance standards and application guidelines for the use of gapless metal-oxide surge arresters. A long-term study of the thermal properties of metal oxide ceramics, widely used in these surge protective devices, revealed the range of stability characteristics of thirteen commercially available materials.

Algorithms were developed for computing the detection efficiency and the location quality of results from the Ontario Cooperative Lightning detection network. These models demonstrated that an additional lightning receiver would reduce the false alarm rate for arming the Load-Generation Rejection Scheme of the Bruce NGS.

A new low-loss ACSR conductor has been developed and tested, and it gives a reduction in AC resistance of 3.8 percent. Use of low-loss conductors could significantly reduce transmission losses without adding to the cost of the transmission lines.

Studies of the thermal behavior of conductors validated Ontario Hydro's state-of-the-art real-time weather monitoring system. Improvements in the use of weather data will lead to improved and safer use of existing transmission facilities.

System Studies

The stability and security of the interconnected power grid remains a concern, with the continuation of locked-in generation at the Bruce Complex and a proliferation of operating interface limitations. To help stabilize low-frequency inter-area modes of oscillation, power system stabilizers have been installed on some of the

Pickering NGS units, with stabilizers for the remainder scheduled to be installed early in 1988. A new power system stabilizer for hydraulic units was developed. Testing at the Sir Adam Beck II GS confirmed the validity of plant models essential for optimizing performance of our automatic generation control system.

In conjunction with the Electronics and Instrumentation Section, a prototype Power System Disturbance Recorder was developed. When installed at several stations, it will allow the acquisition of disturbance data and facilitate the re-creation of system events and the calibration of system simulation programs.

A new relay to protect the stator windings of turbogenerators was developed and applied at Lakeview TGS. It will become the standard for all future installations. Inadequacies in the coverage of some existing impedance-based line relays were identified and remedial action was recommended. Evaluation of protection systems for new applications continued, with the focus turning to relays for protection of series-compensated lines. Equipment has been purchased and new testing techniques have been developed to facilitate the evaluation of several relays for series-compensated line protection.

Fibre-optic technology vies increasingly with microwave technology as a communications medium. Testing was conducted on three different composite fibre-optic skywires to develop standards and to determine their suitability for future application. Radio and television interference continues to be an important area of work, and a major study of interference from distribution lines was completed this year as part of a Canadian Electrical Association (CEA) contract. The quality of the waveform supplied to customers is of increasing concern. To facilitate waveform analysis in the field, a Power Harmonic Analyzer (PHA) has been developed under a CEA contract.

Electrical transients due to lightning, switching or faults must be controlled to ensure system-wide security. Tests and computer simulations led to practical formulas describing the surges which stress generators and large motors. New models of the magnetic behaviour of transformers were developed. Simulations showed that arresters bonding high-voltage cable pipes to station ground required upgrading. Grounding system tests at

Merivale TS have led to improved grounding design procedures.

Stations and Underground

A major project sponsored by the Electric Power Research Institute (EPRI) is underway to improve the reliability of epoxy spacers in gas-insulated equipment. Six subcontractors, located in Europe and in North America are working with Ontario Hydro on a range of failure mechanisms, which include partial discharge in voids, electrical treeing at epoxy and metal interfaces, tracking of surfaces, and long-term chemical and thermal aging. Considerable progress has been made in the factory production of spacers with controlled defects and in the development of advanced diagnostic instrumentation.

To defer the costs of new plant, more precise determination of underground cable ampacities and studies of alternative criteria for loading of one or more underground cable circuits during an outage of a companion circuit are being undertaken. Several field measurements were performed on the 115-kV Riverside Junction to Strachan TS circuits. In addition, advanced computational techniques have been developed for analysis of temperatures in the vicinity of underground cables.

An external agreement was finalized to manufacture and market the Partial Discharge Analyzer for Hydro Generators (PDA-H). A complete coupler installation and servicing package was included. Development of this on-line diagnostic instrument, now in world-wide use, was sponsored by the Canadian Electrical Association. It is credited with annual savings amounting to millions of dollars within Ontario Hydro alone. The final report on the PDA-T, a similar instrument for use with turbine alternators, has been completed, thereby completing a four-year project. Further work is required prior to commercialization.

A five-year EPRI project on the turn insulation capability of large AC motors has been completed and a draft of the final report submitted. This study of one of the major causes of motor failures explored the surge environment in power stations and factors associated with motor insulation strength. Recommendations were made with respect to quality control in motor coil manufacture, cable feeder arrangements, and switching practices. Based on this work, Ontar

Hydro is examining its motor specifications.

A great deal of progress was made on another ongoing EPRI-sponsored project, designed to improve methods for predicting the life of motor and generator insulation systems. Several new types of instruments were developed that permit better on-line thermal, mechanical, and electrical monitoring of rotating machines. In addition, a handbook was prepared to advise utility maintenance engineers on how to evaluate the condition of rotating machine insulation.

A third EPRI project to develop an expert system to monitor generator condition and performance is progressing on schedule. A host utility has been selected to test a prototype system.

This year, activities in the transfer of induction heating technology to Ontario's industries increased. Seminars, consultation services, and feasibility studies on the application of various electromagnetic processes were provided to several outside companies and organizations. These processes include induction heating, annealing, induction brazing, and induction hardening. As well, high-rate-of-energy release techniques are being adapted for controlled breaking of concrete and rock. Research in controlling shock waves as a function of electromagnetic and mechanical parameters is being conducted.



Shown is performance testing of an AC device for spacer repositioning in the CANDU reactor.

Electrical Testing & Development

Analytical and laboratory tests led to significant advances in distribution system technology for the enhancement of the economics, security, and safety of Ontario's distribution plant.

Application of these advances to current problems produced effective technical support for operating personnel. Included were a comprehensive arrester application guide for all aspects of surge protection, including new metal-oxide arrester applications, cold-load pickup practices designed to preclude excessive outage time, user-assisted computer programs to facilitate transformer life estimates and transient recovery voltage studies, and a series of recommendations for minimizing underground cable costs through improved purchase specifications and installation practices. In addition, improved equipment designs continue to evolve from the development of performance requirements and from close liaison with the electrical industry. Negotiations are ongoing with manufacturers to produce and market a fault current diverter protection device and a device to prevent arrester explosions.

Transmission and distribution field and laboratory testing services were enhanced to increase diagnostic capabilities and further improve operational efficiency. In addition, the implementation of digital technology in instrumentation and data analysis systems moved forward. Special

efforts were made to accommodate studies of flashover performance of 500-kV insulation during critical icing and fog conditions. The environmental facilities developed for this program are unique to the industry.

Electronics & Instrumentation

Recent advances in semiconductor technology have had a major impact on the design of electronic equipment for power systems by providing access to the high level of reliability required for applications on increasingly complex electric power systems.

For example, the Programmable Auxiliary Logic Controller (PALC), which was designed some years ago to replace conventional electromechanical relays in station protective relaying systems, has been upgraded to take advantage of the recently developed Application Specific Integrated Circuit (ASIC) technology. An ASIC has been incorporated into PALC which, in addition to implementing the functions of the original digital input circuitry, provides additional redundancy and self-diagnostics, thus providing a reliability level not achievable with conventional integrated circuits. To expand the potential applications of PALC further, an Analog Input Module is being developed to measure the magnitude, frequency and phase of voltage and current signals.

A hand-held recording ammeter called the ERA-3 has been developed to help Regional marketing personnel



Tony Griffin (Research), Carl Kropp (Ottawa Hydro) and Richard Morris (Energy Management Branch) discuss the application of the ERA-3 to collect load data for helping customers optimize their energy usage.

collect load-profile data of a commercial or an industrial customer's power consumption. The data is stored in a solid-state memory that can be read by a computer and analyzed. Using this information, Hydro consultants can help customers make efficient use of their electrical energy.

A portable computerized version of the Soniscope, an instrument used to determine the integrity of hydroelectric dams and other mass concrete structures, has now been completed. By using digital signal processing techniques, the operating range and many other characteristics of the instrument have been significantly improved over the original Soniscope which was developed almost 40 years ago.

A program has been initiated to upgrade the facilities of the Electrical Standards Laboratory which maintains the Corporation's standards for electrical units such as the volt, ampere, ohm, watt and watt-hour. These standards which are all directly traceable to national standards, are used in conjunction with precision equipment to calibrate other working instruments, including those which ultimately ensure the accuracy of our customer billing meters. The upgrade is aimed at providing a state-of-the-art facility to not only improve the integrity of our calibrations, but also the efficiency with which they are made.

Science

The mission of the Science Section is to carry out longer-range research using advanced technology to produce new inspection techniques and to develop new industrial applications for advanced electrical technologies. For example, the holographic technique developed in previous years as a method for assessing the integrity of small objects has been improved for field application and can now be used without elaborate vibration-isolation equipment. This represents a significant breakthrough.

An Industrial Laser Laboratory with a 1.5-kW CO₂ laser was established to explore the industrial applications of high power lasers, such as in the cutting, welding, and surface treatment of metals and ceramics. In addition to meeting Ontario Hydro's internal research needs, the laboratory aims for technology transfer to Ontario industry. Laser-based techniques, such as laser-based phosphor thermometry which allows remote temperature



Engineers conduct the field testing of the newly redesigned Soniscope.

measurement, were developed. An application of this is a prototype rotor temperature sensor which was built for EPRI to monitor the temperature of rotors in turbo-generators for diagnostic purposes.

Research activities in support of the Corporate-wide Biological Effects of Electromagnetic Fields program have been substantially expanded. Advanced instrumentation and test techniques to measure the environmental impact of electrical and magnetic fields from power lines and to evaluate risk hypothesis in the laboratory were developed. This work forms

part of the recently created research collaboration in this area between Ontario Hydro, Hydro Québec and Electricité de France.

The discovery of High Temperature Super-conductors (HTSC) in 1987 may have significant impact on Ontario Hydro's future power system. A HTSC Task Force was formed to monitor this new development and study potential applications. Research in material fabrication and characterization was carried out in a number of sections.

The Section has developed a computer-vision based seam tracker for automatic welding which will be incorporated into a system being built by the Metallurgical Research Department. In addition, the Section has developed expert systems in the areas of protective coatings and the interpretation of eddy current signals, which are used to diagnose faults in pipes. Expert systems improve effectiveness by enabling others to deal with routine questions without the direct assistance of experts. A Robotics and Artificial Intelligence Laboratory (RAIL) with an Apollo work station is being prepared for research into autonomous robots for use in hazardous environments. The benefit to cost ratio from having an autonomous robot carry out repair or decommissioning work in a nuclear environment is enormous. The Research Division has joined the Pre Competitive Applied Research Network (PRECARN), which is a



Tritium separation requires high-power pulses from a CO₂ laser system, shown here being adjusted with the aid of a helium-neon laser.

non-profit company that sponsors research into artificial intelligence and robotics.

Separation of tritium and carbon-14 from effluents in fission and fusion reactors by lasers and by cryogenic distillation was examined, and preliminary results show that the two processes are competitive with conventional separation processes. Measurement of the fundamental parameters required for building a pilot plant is underway. The purpose



A Robotic and Artificial Intelligence Laboratory has been set up to develop, amongst other things, a robotic system for use in hazardous environments.

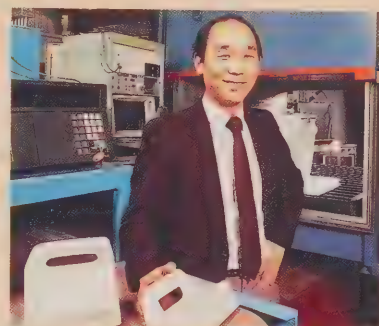
of this work is to develop new and effective disposal options for Hydro, and to help the fusion community speed the development of an effective fusion power source. Selective depletion of zirconium-91 has been demonstrated in experiments using Atomic Vapour Laser Isotope Separation (AVLIS). The experiments were performed in collaboration with the National Research Council of Canada. AVLIS for zirconium separation is of interest because the zirconium depleted in zirconium-91 has a lower neutron absorption cross-section, which allows greater flexibility in nuclear reactor design. In addition to isotope separation, the nuclear science group developed a device able to verify fuel bundles in the spent fuel bays so that Hydro can meet its obligations to the International Atomic Energy Agency (IAEA).

Utilization

To help Ontario Hydro customers gain increased benefit from electrical power, the Utilization Section tests and develops more efficient and effective uses of electrical energy.

Sixty-five Ontario industries worked with the Section during the past year to evaluate the usefulness of various electrotechnologies for their

processes. Some remarkable advantages were identified through cooperative testing in the Process Applications Laboratory, and as a result, several Ontario companies are implementing new electrotechnologies to increase their efficiency and improve their competitive position. In addition to this type of assistance, basic development continues on industrial heat pumps and dehumidifiers, advanced ceramic processes, and low-temperature plasma.



Ontario industries benefited from cooperative studies with the Utilization Section. (Top) This year, product testing led to the installation of a microwave dryer at a Toronto ceramics company. The dryer reduces process time from twenty-four hours to about eight minutes. (Bottom) Work with an Ontario manufacturer was conducted to improve the performance of an innovative heat pump. The upgraded appliance has attracted world-wide attention.

In the residential sector, the emphasis was on space and water heating. Of prime importance was the heat pump, and work to further develop and popularize this type of system was carried out. Ontario Hydro has developed a heat pump which is highly efficient at very low outdoor temperatures. In addition, researchers have worked with industry to achieve a variety of new heat pump designs with very low winter peak power demands. The performance of several systems is being measured in installations throughout Ontario, some in cooperation with the Swedish State Power Board.

Strategic conservation measures, such as those provided by the Division's heat pump research, benefit

Ontario Hydro and the Municipal Utilities and offer energy consumers greater value than other options. Other work designed to help customers save energy focused on improving window technology, retrofitting insulation and improving building ventilation.

Tests in residential and commercial ventilation heat recovery for domestic hot water production have been conducted. Results show potential for widespread use, especially in commercial areas. One restaurant demonstration won the prestigious American Society of Heating, Refrigerating and Air Conditioning Engineers award for outstanding achievement in energy efficiency.



The Queenston - Chippawa plant (Sir Adam Beck GS #1) at dinner time in 1919.

Manager's Report

The Mechanical Department is a research and development resource which provides technical expertise and experimental and testing facilities related to the mechanical disciplines.

The Department is organized into four Sections, each with a specific functional responsibility to deliver

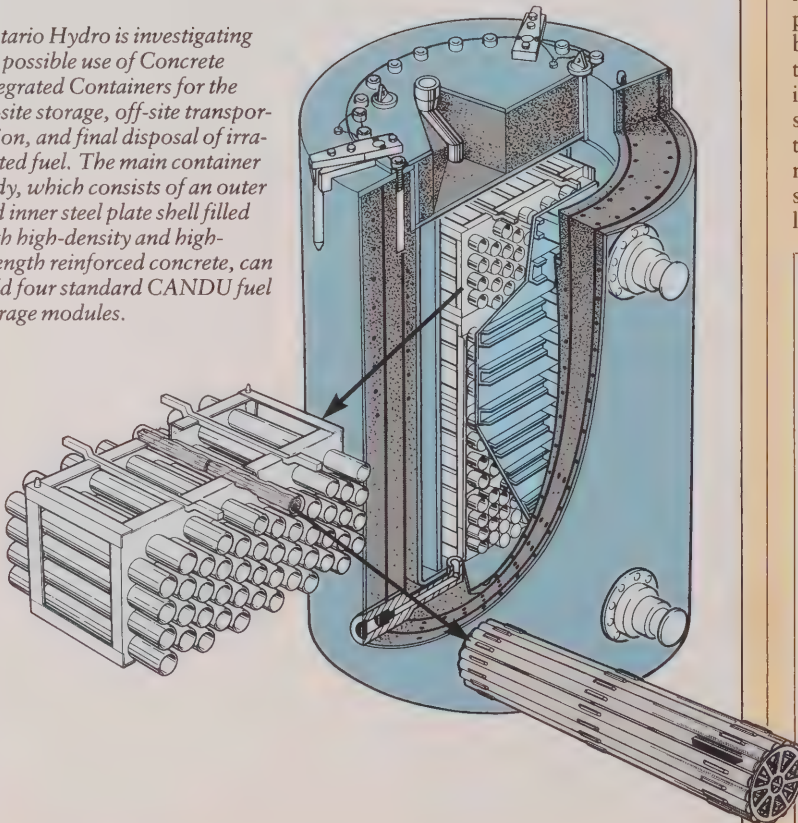
products contributing to the improvement of performance, reliability and safety of components and mechanical processes utilized in Ontario Hydro's overall operation.

Resources include 94 professionals and technical support staff. The annual operating budget is 8.8 million dollars. In 1987, activities spanned areas ranging from the development of

mechanical performance requirements for fibre-optic cables to full-scale testing of an 11,000 horsepower, primary heat-transport pump for Darlington NGS. In addition, a Senior Research Engineer leads and directs long-term corporate research needs on the structural aspects of the transmission and distribution systems.

The Senior Research Engineer's most important initiative in 1987 dealt with aging transmission lines. As the age of transmission lines increases, with the oldest now past the 80-year mark, an investigative program to help prioritize lines for refurbishment has been initiated. Preliminary investigations indicate that outage rates increase with line age, making necessary a major effort to upgrade lines that have been in service for 50 years or more. Subsequent to these findings, on site investigations of sections of older lines in the process of being replaced

Ontario Hydro is investigating the possible use of Concrete Integrated Containers for the on-site storage, off-site transportation, and final disposal of irradiated fuel. The main container body, which consists of an outer and inner steel plate shell filled with high-density and high-strength reinforced concrete, can hold four standard CANDU fuel storage modules.



MECHANICAL

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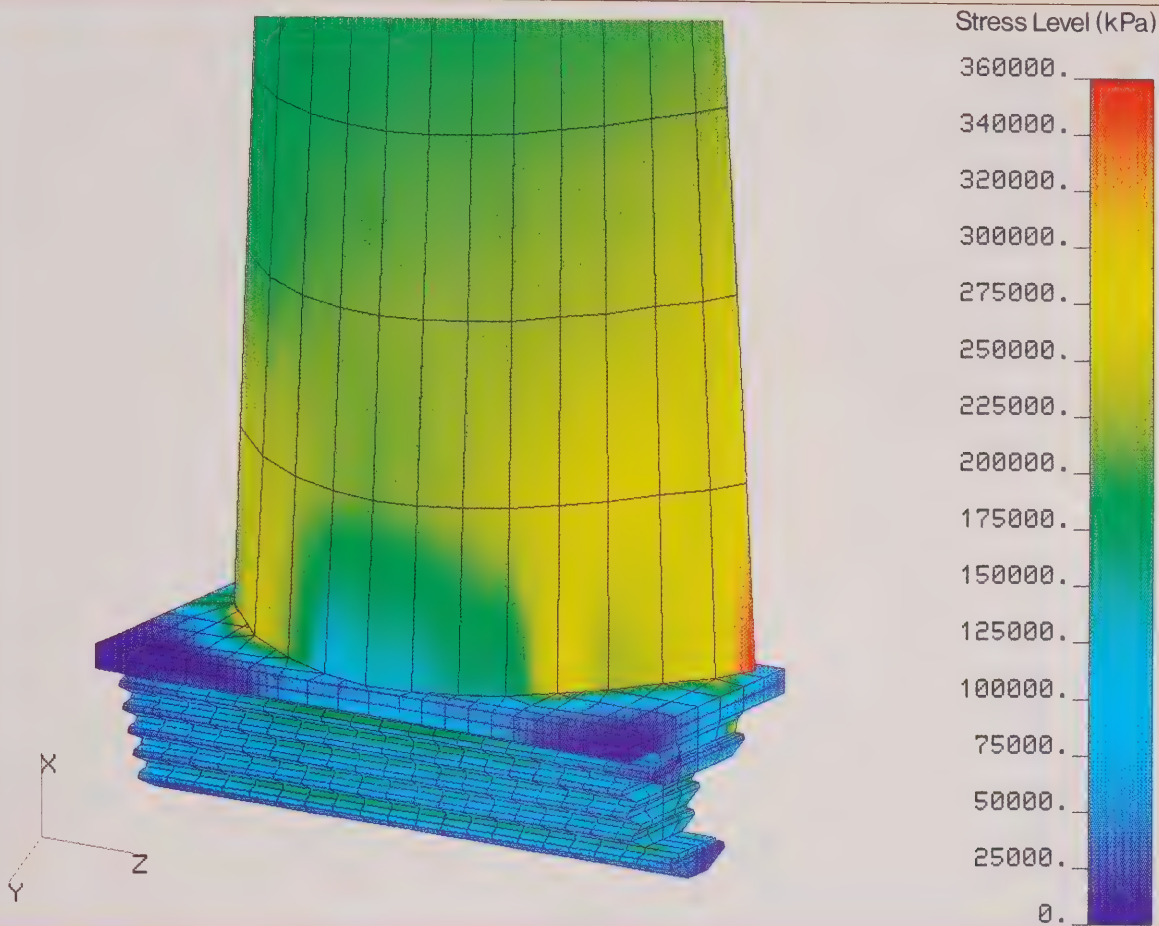
Nuclear Process

Components Test Facility

Dr. R.T. Hartlen

Plant Equipment Dynamics

Mr. T. Loewen



A stress analysis was conducted at Nanticoke on the root of a low-pressure turbine blade. The results of the analysis of the high stressed areas are shown here (indicated in red) and correspond to the regions where cracks in the root were found.

for unrelated reasons, were initiated. Data on the condition of conductors, overhead ground wires, insulators, hardware, towers, and footings are being obtained through field inspection, sample testing, and in-situ destructive tests on structures and foundations. The test program is aimed at the identification of mechanisms and rates of deterioration in different locations and the development of simple techniques of condition evaluation that can be applied in the field. The results will help prioritize candidate lines as part of a rational refurbishment program.

Plant Equipment Dynamics

Services and research performed by this Section focused on improving the reliability of plant equipment and reducing operating costs.

During the commissioning of units at Darlington NGS and other nuclear generating stations, vibration measurements and analyses performed on machinery, process equipment, piping systems, and structures contributed to the identification and resolution of a number of vibration-related problems. Similar problems in operating plants were investigated and corrected.

In generating stations, significant progress was made in the development and implementation of machinery condition monitoring systems. These systems provide information that allows the optimization of plant maintenance. Computer-based vibration monitoring systems, with portable data acquisition units and software customized to meet plant requirements, were implemented in Bruce NGS 'A', Darlington NGS, and the Bruce Heavy Water Plant. In addition,

an on-line monitoring and diagnostic system, developed for evaluating the condition of critical pump sets, was installed at Darlington NGS. Significant progress was made toward the development of a system for evaluating the condition of nuclear and fossil plant turbine generators. An EPRI-funded research project on condition monitoring of hydraulic generators was completed with the installation of two demonstration units.

Services were provided in controlling environmental and plant noise. High-voltage transmission line corona and transformer station noise have been investigated.

Mechanical Testing and Development

In addition to mechanical and structural testing the Section performs seismic and environmental qualifications

and conducts studies in tribology, fluid mechanics, heat and mass transfer, and two-phase flow.

The safe operation of aerial devices is of concern. In practice, this type of device is often subjected to a horizontal load because the conductor is supported by the device during line construction and maintenance operations. Thus, a load chart for a Pitman HS-50 aerial device has been developed that ensures that neither strength nor stability limits are exceeded under combined vertical and horizontal loads. A related development is a jib-load sensing device. The device ensures safe operation of bucket trucks and other aerial devices under all loading conditions.

Distribution class wood poles are being tested in our newly-developed fully-automated pole-test machine. The results are part of a program to compile a data base that will be used to formulate a rational and economical replacement program.

The seismic and environmental qualification program in support of Ontario Hydro's nuclear program continues. Items of electrical and mechanical equipment, mostly destined for Darlington NGS, were tested. Various sizes of masonry anchors from different manufacturers were seismically qualified, and load relaxation tests on masonry anchors were completed.

A CANDU pressure tube may sag and make contact with a calandria tube if the garter springs are displaced from their intended locations. This can cause the formation of hydride blistering and the consequent cracking of pressure tubes. Experiments were performed to measure the temperature field and to determine the effect of fretting in the contact area. This type of information is necessary because temperature gradient is the mechanism driving the migration of hydrogen.

Wear problems were investigated in the ball screw in the Bruce NGS 'B' fuelling machine and in the stopper liner in the Pickering NGS steam release valves. Lubricants were also assessed using ferrography.

Nuclear Process Components Test Facility

The Nuclear Process Components Test Facility's work program consists primarily of providing testing services to internal and external clients.



Seismic tests are being performed to verify that this air conditioning duct can withstand a seismic event without leaking. The air conditioning system, which cools critical equipment at Darlington NGS, has ducts designed with special flexible joints and is supported on rigid hangers.



Hot pressurized water flashes into steam and aerosol as it escapes from the nozzle. This pressurized-water "blowdown facility" is part of the program for modelling the aerosol behaviour of CANDU containment systems.

One highlight of 1987 was the construction, commissioning, and early operation of the new 'PV2' test facility. The purpose of this medium-scale test loop is to investigate process unsteadiness and piping vibration, that can occur under conditions of pumped two-phase steam-water flow. This situation may arise when the primary heat-transport circuit loses pressure due to a small leak. Results from this project will help safety analysts and piping designers analyze the depressurized circuit situation, determine operating limits, and assure piping integrity.

Service to external clients included the successful completion of a special test designed for another Canadian utility. This testing program provided information which led to the elimination of severe noise, vibration, and dynamic stresses caused by an orifice in the heat transport system. A mock-up of part of the system was con-



An articulated manikin is used in the testing of equipment designed to protect personnel from falls.

structed and connected to the main test loop for flow testing. The problem encountered in the plant was simulated, and a modified orifice assembly was developed. The laboratory test program was successful, the field application proven, and thus an operating limitation has been removed.

A new area of work is the qualification of components required to perform safety-related control functions under harsh environmental conditions which could be created by the release of either pressurized hot water or steam into a power plant. Environmental-qualification testing is performed in a separate facility equipped with various test chambers. During the past year, tests were performed on components such as solenoid valves, limit switches, and terminal boxes. Toward year-end, preparations were underway for a major steam-environment test of a heat-transport-pump circuit breaker.



Measurements are taken of the energy absorption properties of commercial vibration dampers for transmission lines. Unless controlled, wind-induced vibration of conductors and overhead ground lines lead to fatigue and wear of conductors and hardware, which causes increased maintenance and shorter service life. Better knowledge of damper properties is leading to more reliable performance of existing lines.

Applied Mechanics

The Applied Mechanics Section carries out research and development aimed at improving the reliability of the structures and equipment that make up Ontario Hydro's power system. In 1987, the Section was active in supporting the Corporation's nuclear and thermal generation, transmission, distribution, and nuclear waste management programs.

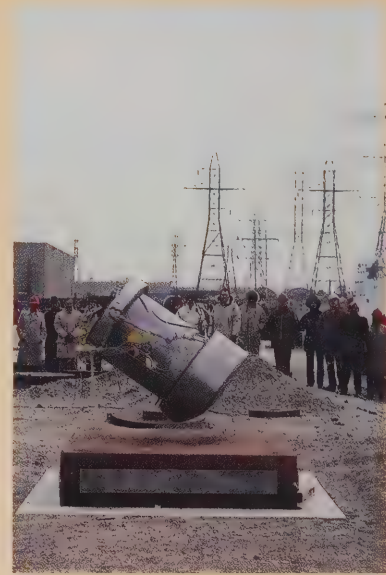
Analysis of zirconium hydride blister growth in reactor tubes was one important area of study. Build up of hydrogen and deuterium in pressure tubes can result in the formation of brittle deposits. Termed blisters, these deposits have an adverse effect on tube strength. Mathematical models were developed to predict hydrogen transport, blister growth, and to indicate the useful life of tubes under a variety of service conditions.

Construction has begun on a laboratory where pressure tests will be performed on large vessels and piping

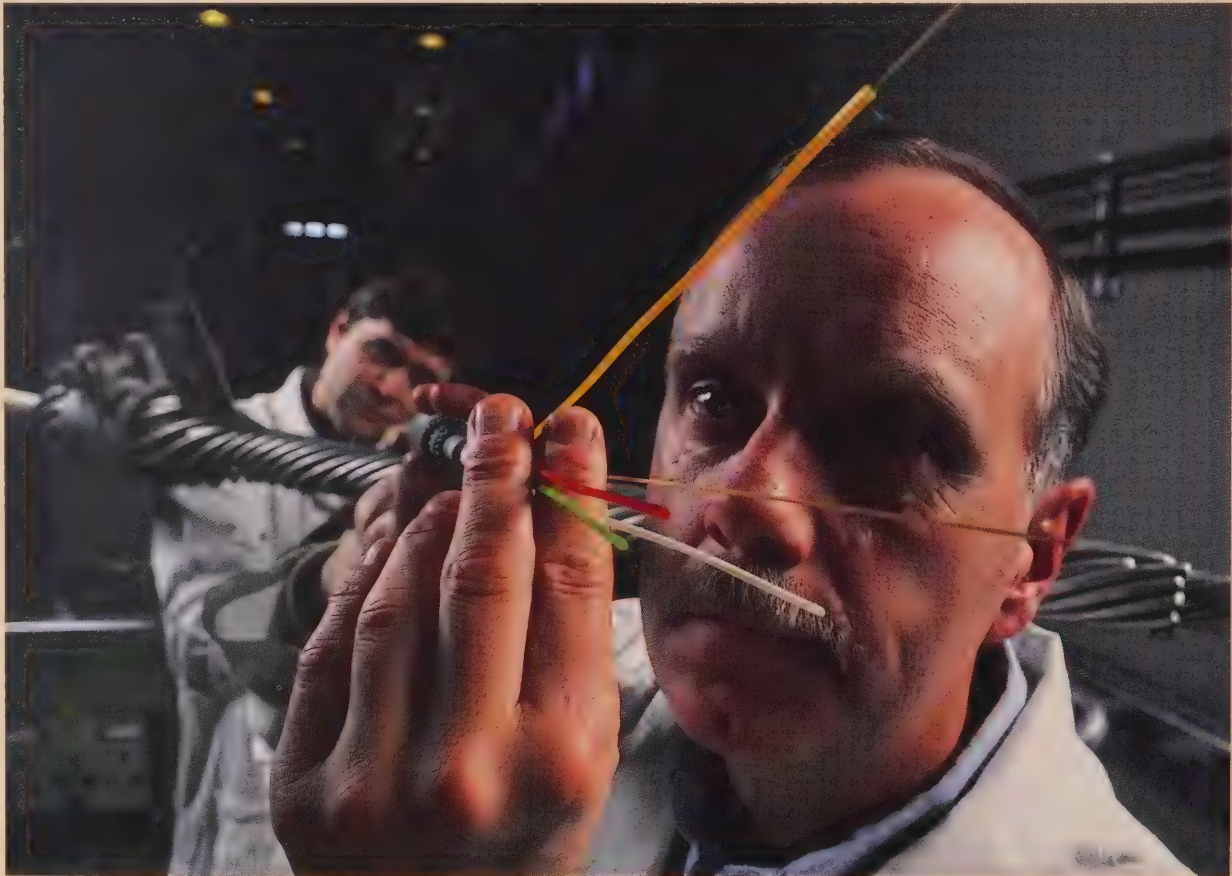
components. The facility is so designed that tests can be continued safely to the point of failure. The facility will be used to study the behavior of pressure vessels in extreme loading situations.

The Section is involved in the development of safe methods of transporting nuclear waste and performs tests on prototype containers. In 1987, a cask for road transportation of irradiated fuel, and packages for transporting operating wastes were tested.

Ontario Hydro is reviewing the feasibility of installing special ground wire cables on its transmission towers; these cables contain a bundle of optical fibres. The optical fibres, which are entirely immune from electromagnetic interference, can be used for telecommunications. The Applied Mechanics Section has built an experimental rig to evaluate the reliability of fibre-equipped cables under simulated service conditions. Cables from various manufacturers are currently under test.



Personnel observe drop tests of scale models of steel concrete casks performed to obtain data for the development of scaling parameters.



The vibration resistance and the mechanical properties of a novel overhead ground wire with a glass fibre optic core for use on high-voltage transmission lines are under study.



"Paying-out" power cable in 1921.

Manager's Report

The Metallurgical Research Department provides a resource comprising specialized facilities and advanced knowledge in physical metallurgy, materials science, and nondestructive testing. The work of the Department was dominated in 1987 by projects designed to meet the objective of maintaining the reliability of Ontario Hydro's CANDU nuclear units.

Hydrogen uptake by zirconium alloy pressure tubes is a life-limiting process. Corrosion processes, believed to be a major contributor to hydrogen uptake, were the subject of extensive study. Similarly, studies of the effect of hydride on the integrity of pressure tubes continued, particularly in the areas of delayed hydride crack initiation and growth, and blister formation. Other work impacting on fuel channel performance included deformation experiments and research into the limitations and applicability of nondestructive testing techniques for defect detection and evaluation.

Other components of nuclear generating plant also received attention. Tube corrosion under sludge deposits is the most significant cause of failure in nuclear steam-generators worldwide; thus, the Research Division program focuses on the tube-sheet region of CANDU steam generators. In addition, fracture mechanistic studies showed that, if failure did occur in the large-diameter heat transport piping, it would be by a leak-before-break mode rather than by a catastrophic one. This finding contributed in part to the licensing of the Darlington Nuclear Generating Plant.

Research addressing the current needs of thermal plants centred in life assessment. Techniques for interpretation of microstructural changes that occur in key components operating at high temperature were developed and

used at Lakeview TGS. A project supported by the Canadian Electrical Association on robotic weld repair of hydraulic turbine runners saw the commissioning of a robot and advances in system software for automated welding.

Significant transfer of technology occurred, particularly in areas associated with tritium handling. Furthermore, the Department continues to provide a problem-solving service in the materials area, and a variety of problems involving failure analysis and corrosion were addressed. General consulting services and support for the development of a number of industry standards were maintained.

The Department's Senior Research Engineer continued his close collaboration with the Nondestructive Evaluation (NDE) Unit to further develop techniques and equipment for

METALLURGY

Manager

Dr. J. Brown

Senior Research Engineer

Dr. M.P. Dolbey

Corrosion & Tritium
Technology

Dr. P.C. Lichtenberger

Materials Integrity

Dr. R.G. Fleck

Metallurgy

Dr. W.H.S. Lawson

Nondestructive & Fracture
Evaluation

Dr. J.A. Baron



In-situ metallography is being performed to assist in determining the remaining life of a turbine-loop pipe-weld at Lakeview TGS.

the assessment of the condition of zirconium alloy pressure tubes in CANDU nuclear reactors.

To ensure the use of defect-free pressure tubes, optimal manufacturing inspection is required. The record is good, but operational experience indicates room for improvement. Thus, work is underway in cooperation with the Nuclear Generation Division, Atomic Energy Canada Limited (AECL), and various tube manufacturers to identify and implement improved inspection equipment and procedures. These were used for inspecting tubes intended for use in the Darlington NGS Unit 4 reactor. A study of inspection signatures from acceptable new tubes was undertaken to determine their impact on interpretation of in-service inspection results.

There is a need for a nondestructive method of measuring the amount of hydrogen that exists in pressure tubes. A method developed by the Department's Materials Integrity Section is encouraging and is being adapted for use in our reactors.

Since the Channel Inspection and Gauging Apparatus for Reactors (CIGAR) system was conceived, the extent and the method of inspection techniques have changed radically. Consideration is now being given to a new inspection system able to operate independently of the main components of a reactor's fuel handling system.

Metallurgy

In 1987, the Metallurgy Section initiated a major technology advancement through work on the robotic repair of hydraulic turbine runners. The project was performed in collaboration with the Institut de recherche d'Hydro-Québec and was funded by the Canadian Electrical Association. The robot has now been commissioned and is able to weld. More important is that the technology secured advances in system software, which include concepts of artificial intelligence and self-programming.

Among other applications, pulsed-gas metal-arc welding, which is the process of choice for turbine runner repair and for automated and manual pipe welding, has been the target of an intense reliability improvement program. Several types of characteristic defects were identified and the practical limits of the process defined for critical applications, such as in temper-bead welding.

The Section plays a central role in the development of the Corporation's welding standards. This is done by carrying out qualification testing and by arranging regulatory approvals for all standard welding procedures.

As a major centre for development of welding technology for spent nuclear fuel containment, the Section completed process definitions for all

container designs and materials currently under study.

Through its work on metallurgical failure analysis, the Section plays a major role in problem solving. Diagnosis of fatigue cracking of the moderator recirculation pipework at Pickering NGS Units 5 to 8; remediation of cell connector and cover defects in station batteries; discovery of a widespread quality problem in the manufacture of fuel injection nozzles of gas turbines on emergency generators; definition of a remedial program for flange stud fractures at the Bruce Heavy Water Plant; and evaluation of the condition of preemptively removed steam generator tubing were items dealt with during the past year.

The Section continues to give decision support in life assessment of fossil-fired generating units. Metallography based on replication offers the only nondestructive means of determining the status of components operating in the creep (high temperature) regime. For example, assessment work continues at Lakeview TGS. All the replication done in the field at Lakeview is now complete. Laboratory analysis of data obtained from Units 4 and 7 is in progress, while that for Unit 1 is complete. Life assessment evaluations have been performed on samples of boiler and condenser tubing that were removed preemptively. Whereas most components were in good condition, decisions regarding their replacement may become necessary in the near future.

Frequent failures of aluminum castings, invariably attributable to poor alloy selection or unacceptable foundry practice, led to the development and completion of a laboratory investigation of the problem. Dramatic improvements in the properties of small laboratory castings were demonstrated to be the result of merely careful attention to alloy and process control within normal working ranges. Client acceptance of this demonstration has been excellent. As of year end, a client-funded demonstration of our recommended practices is being carried out under our supervision in a local commercial foundry.

Corrosion and Tritium Technology

Corrosion of zirconium alloy pressure tubes and their subsequent hydrogen uptake provided a major area of study for the Corrosion and Tritium Technology Section. The life



In cooperation with researchers at IREQ, and with co-funding support from the CEA, a portable, compact robotic system is under development for the in-situ repair of cavitation damage in hydraulic turbine runners.



Strong aluminum castings with vastly superior ductility and fracture toughness properties were produced through cooperative research with Brampton Foundries.

of nuclear reactor pressure tubes is directly related to the rate of hydrogen uptake. The principle source of this hydrogen is believed to be associated with the waterside corrosion process. Thus, a program is underway to quantitatively establish the influence of the key parameters of temperature, water chemistry, oxide characteristics, surface condition, and alloy and impurity effects. Both normal and accelerated testing are being used. To simulate the end-of-life condition of oxides on reactor pressure tubes, thick oxides, grown artificially on test coupons, have been produced and installed in fuel bundles in several CANDU reactors to generate a base of reactor-relevant data.

Detailed characterization of the oxide, the metal-oxide interface, and the bulk alloy allows correlation of the results of parametric exposure testing and of corrosion and hydrogen uptake measurements. Intermetallic formation, other reactor operation-induced microstructural changes, and the development of oxide porosity, cracking, and spalling are being studied to establish rate controlling processes for the hydrogen uptake mechanism.

Predictive modelling based upon parametric functional relationships is under development. Predictions have already been generated to assist the planning of Repositioning of Endfitings and Bearings (REFAB) and Spacer Location and Repositioning



A uranium-hydride storage bed has been developed for the temporary storage of tritium at Darlington NGS. Using three kilograms of depleted uranium, the beds have a rated storage capacity of 52 grams (500 kCi) of tritium.

(SLAR), and the making of decisions to retube.

Corrosion of nuclear heat exchangers and steam generator tubing provides another fertile area of investigation. Heat-exchanger test rigs are in operation at the Pickering and Darlington Nuclear stations to study localized corrosion initiation and propagation effects using Lake Ontario water as a function of tube deposit buildup, microbiology, and tube material. The rigs facilitate realistic testing of remedial measures, which include chemical cleaning and biociding. Laboratory immersion and electro-

chemical simulation tests are used to gain further understanding of corrosion degradation processes. Initiation probability and propagation rates in lakewater have already been determined for a number of alloys in current use.

In pressurized water reactors, steam generator tubing is susceptible to stress corrosion cracking, localized corrosion under sludge deposits, and corrosion fatigue. To predict the susceptibility of CANDU to these mechanisms, exposure testing using laboratory simulations is being carried out to establish a data base applicable to CANDU

operating variables. Temperature, alloy heat treatment, and water chemistry are considered key factors.

Tritium technology is another significant interest of the Section. A hydrogen pump, which relies on the permeation of atomic hydrogen through bilayer metal membranes, has been developed. This equipment features high pumping rates at high compression ratios. A potential commercial application is to fusion reactor systems which are required to pump tritium and to purify fuel and exhaust streams. The concept is also being tested as a diagnostic probe on the TEXTOR tokamak to measure hydrogen fluxes under various operating conditions.

The safe management of tritium requires that it be stored under well-controlled conditions. Metal getter research has progressed sufficiently to permit efficient immobilization of tritium on uranium and zirconium-iron beds. High performance, doubly-contained storage beds of 25g and 3,000 g size were designed, constructed, and tested to measure hydriding rates under a variety of conditions. The 3,000 g beds were commercialized and installed at the Darlington Tritium Recovery Facility (TRF). The technology also has commercial potential for processing fusion reactor exhaust systems and for purifying inert gas glovebox environments.

Technical support to the Darlington TRF included leak testing calibration, tritium monitor testing, and assistance with operating manual documentation. Final operational commissioning of the tritium immobilization system is underway. Consultation services have been made available to the University of Rochester and to Hydro's own Tritium Application Program.

Materials Integrity

The Materials Integrity Section has been extensively involved in the study of delayed hydride cracking, pressure tube fracture, and the effects of irradiation on the deformation performance of standard and modified pressure tubes.

Studies on the influence of hydrides on pressure tube performance focused on delayed hydride crack initiation and growth, and on blister formation and cracking. Of significance is the development of a probabilistic model that is able to assess the state of the

core of a reactor with respect to blister formation and cracking that may be initiated when pressure tube-to-calandria tube contact occurs. This work has been accepted as a key predictor of the occurrence of blister problems in Pickering NGS Units 3 and 4. Further work in this area evaluated the movement of hydrogen under fret marks which developed in the commissioning of Pickering NGS Unit 8. It was demonstrated that hydrogen moves away from these marks. From this observation, the Atomic Energy Control Board deferred tube removal to permit hydride distribution at fret marks to be established.

In the evaluation of pressure tube integrity, a key factor is knowledge of the hydrogen concentration in the tubes. A technique for the nondestructive in-situ measurement of hydrogen concentration has been developed in the laboratory. Hydrogen concentration is determined by detecting changes in resistivity with temperature variation; the phenomenon has been successfully demonstrated in small specimens and on a section of a pressure tube.

Irradiation growth tests on pressure tube materials continued in the DIDO reactor at the Atomic Energy Research Establishment at Harwell, UK because the neutron flux in this reactor is higher than in the CANDU. Test specimens in the DIDO reactor have exceeded the neutron fluence of pressure tubes in the CANDU reactor with the longest service. Power reactor deformation data have been analysed and compared with the predictions of design equations. Of particular importance was the modelling of pressure tube-to-calandria contact in relation to the time-to-contact and the location of the contact.

In support of safe reactor operations, a program to establish handling criteria of partially oxidized fuel cladding has been carried out. The mechanical strength of the cladding was established by post-oxidation tensile tests at ambient temperatures and by biaxial deformation during the oxidation process. These criteria will be used to inform operations staff about the potential risk of fuel clad failure when handling partially oxidized fuel cladding.

Nondestructive and Fracture Evaluation

Fracture mechanistic studies were

used extensively in the Darlington NGS leak-before-break project. The objective was to demonstrate that large-diameter, primary heat-transport piping would, if subject to failure, fail in the leak-before-break mode rather than in the sudden guillotine or other mode. This program encompasses significant elements of material testing with an emphasis on weldments and zones affected by heat, and analytical elastic-plastic fracture mechanics. The project has generated excitement on an international scale, primarily in Japan and the United States. If this project had failed to realize its objective, the licensing of the Darlington station would have been jeopardized.

Work in the Nondestructive Evaluation Unit was directed at fuel channel inspection capability. The Unit had significant involvement in the Package Inspection Probe for Rolled Joint Evaluation (PIPE) project which in one week was successfully commissioned and utilized to inspect 110 rolled joints in Bruce NGS Unit 2. Work on the Pickering version of PIPE has been extended to allow rapid inspection for the location of garter springs and blisters. Significant assistance has been provided to Central Nuclear Service to upgrade Channel Inspection and Gauging Apparatus for Reactors (CIGAR) capability. This has involved integration of a computer, an optical disc, and new software, which replace the original gauging system and the flaw detection data system. Further development of curved-line focused probes for the SLAR system has been undertaken.

Other fuel channel-related activity has been aimed at investigating various approaches to hydride platelet concentration measurement and the estimation of blister crack depths. A technique for hydride platelet measurement readily adaptable to fuel channels has not yet been discovered, but the application of scanning acoustic microscopy looks promising.

Ultrasonic crack tip diffraction signals have been processed according to time of flight, and in thick pressure boundary material, synthetic aperture techniques yield excellent estimates of defect position and size. This advancement is essential in the fitness-for-purpose analysis of pressure boundary components as it enables reasonable precision in the sizing of defects.



A scene from the Hydro Shop of the London Public Utility Commission in 1944.



Operations Research personnel discuss how a microcomputer might resolve a scheduling problem.

for desk-top publishing and presentation graphics. To enhance file transfer and sharing of resources, a local area

network was acquired for the computer room. The Research Division's Integrated Computing Environment (ICE) Planning Project was successfully completed under leadership provided by the Section. The recommendations of the ICE Planning Project were endorsed by the Research Executive.

OPERATIONS RESEARCH

Manager
Mr. J.G. Cassan

Operations Research
Dr. A.H. Chung

Reliability & Statistics
Dr. J. Endrenyi

Reliability and Statistics

For many years, the Reliability Unit of the Section has been involved with the development of mathematical models of system reliability and their applications. The aim of this work is to assist Hydro's planning, operating, design, and maintenance functions. Typical projects undertaken by the Unit this year were the development of

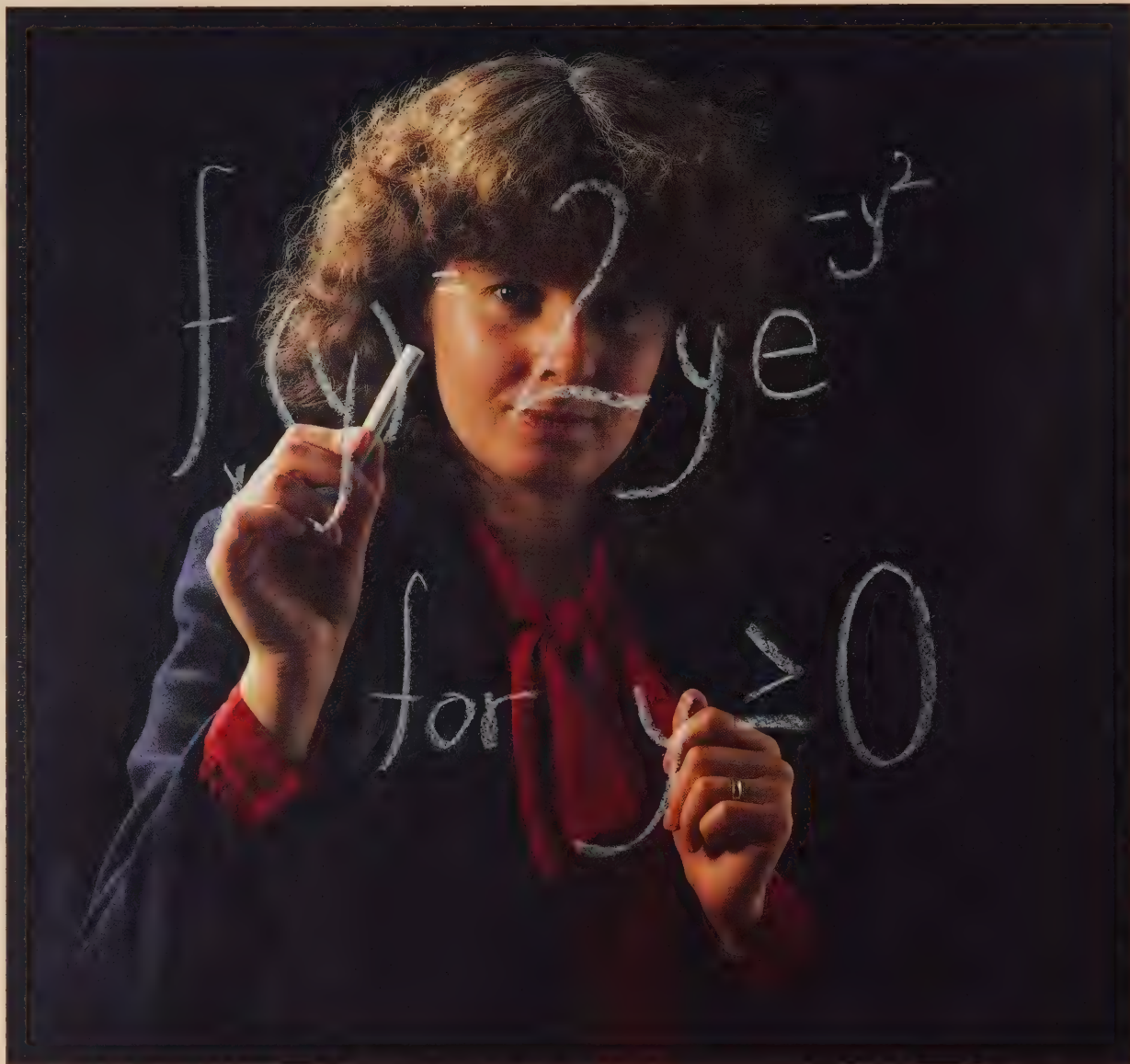
Manager's Report

The Department provided ongoing services to numerous Corporate clients. The client base and the range of services has been expanded in the areas of operations research, statistics, and power system reliability. Specialized computer support services were provided to research staff.

Operations Research

Operations Research (OR) is a label coined in WW II to describe the scientific analysis of military operations. Since then, the term has been widely used in business, industry, and government. For over 30 years, the services of operations researchers have provided clients in Ontario Hydro with practical and cost-effective solutions to a variety of problems. In 1987, the OR Unit focused its efforts on operational efficiency enhancement for clients. During a year marked by significant diversification in areas of applications, it has provided problem-solving services and has developed decision support systems for ten Hydro Divisions. In anticipation of the needs of the Corporation, the OR Unit continued to enhance its capability in expert systems with the development of two prototypes: one for a signing authority register, the other for literature searches.

The Computer Support Unit continued to provide specialized programming and consulting services to the staff of the Research Division. The Unit also increased its efforts in the research, evaluation, and introduction of new computer technologies. In 1987, a workstation designed to run true three-dimensional Computer-Aided Design and Drafting applications was evaluated and acquired. Facilities were purchased and installed



Our highly skilled statisticians are always ready to resolve client problems.

a much needed method for estimating confidence bounds for a Monte Carlo simulation program used by the Power System Operations Division and a reliability assessment of the control and operating facilities to be installed at the new System Control Centre at Clarkson.

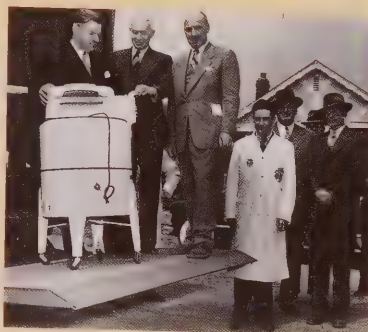
Reliability Unit staff have earned an international reputation through publications and participation in committees and conferences. This year, staff gave seminars in China and Israel, and participated in a workshop sponsored by the National Science Foundation. Staff participated in a CIGRE

project which produced an application guide for power system reliability analysis.

The Statistics Unit was formed several years ago when a Corporation-wide need for expert assistance in data collection and evaluation was perceived. Such assistance appeared to be most welcome when interpretations had to be made of data that were scarce, interrelated, dispersed, or even contradictory. The Unit's reputation is now well established both inside and outside the Division.

Studies, typical of the diversity of

projects taken up by the Unit, include a proposal for a national sampling plan for revenue meters, which was developed under a Canadian Electrical Association contract; a statistical evaluation of the error in estimates of reactor channel powers; a forecast of Niagara River flows; the identification of relationships among performance and cost indicators for all sources of energy production; and the estimation of hot water system sizes for multi-residential buildings. In addition, assisting clients through informal consultations continued to be a daily part of the Unit's activities.



In May 1944, Hydro officials check a washing machine converted to operate on 60-Hertz service as part of the Frequency Standardization Program.

The Divisional Services department provides support to the whole Division. These services include report production; business administration; financial reporting; records, space, and safety management; printing and clerical services; model shop production; drafting; photography; payroll; and editorial services.

This year a Strive For Excellence Program was initiated. The vision statement is as follows: "We intend to be an excellent service unit that helps the Division to do its work better. We strive for excellence in service to our customers through the commitment and the abilities of our people." The four values of the Strive For Excellence Program are excellent performance, customer satisfaction, respect for people, and reasonable service costs. Highlights of the program included a one-day seminar for section heads, publication of a services and standards manual, recognition for extraordinary performance, emphasis on employee safety, the use of rotations for staff development, better staff

communications, and better monitoring of costs.

The Department's capability was extended, notably in the Model Shop and Drafting Office. New machines have enabled the Model Shop to produce higher quality work and to concurrently improve productivity. The use of computer-aided drafting has increased drafting productivity. In addition, the photography section is upgrading its capability, particularly in video recording techniques.

The Integrated Computing Environment Planning Project was completed and Divisional Services is now supervising its implementation. The aim of this project is to link computers and other electronic equipment throughout the Division. The capabilities of researchers will be enhanced by improving client interactions, by allowing access to more comprehensive decision-making information, and by allowing new work to be under-

taken that was not previously economically feasible. Costs will be reduced by electronic storage of information, sharing hardware and software, and more cost-effective information processing.

Other highlights were the production of the Research Division's Business Plan and the development of a plan to improve the Divisional management of records. The Drafting Office and the Photography Section made major contributions to the Division's 75th Anniversary celebration though the provision of artwork and photographs, which were used throughout the Division.

The Model Shop utilized their new capabilities to make a notable contribution to the Spacer Location and Repositioning (SLAR) program by successfully undertaking the production of 50 high-performance coils for fuel-channel spacer relocation, thereby permitting Ontario Hydro to meet all AECL's scheduling requirements.

DIVISIONAL SERVICES

Manager

Mr. J.B. Brown

Business Administration

Mr. G.E. Craig

Drafting

Mrs. W. Zwolakowski

Research Publications

Dr. G.R. Floyd

Information Management

Mrs. C. Moraes

Model Shop

Mr. C.P. Stearns

Photography

Mr. K.R. Buck



Prototyping nuclear inspection heads at the Research Machining Facility.

At the end of 1987, the Division's personnel resources consisted of a total regular staff of 649. The percentages of funds allocated to major work programs, the application of staff in various categories of work (Divisional Services Department excepted), and the distribution of staff in broad occupational classes are shown below.

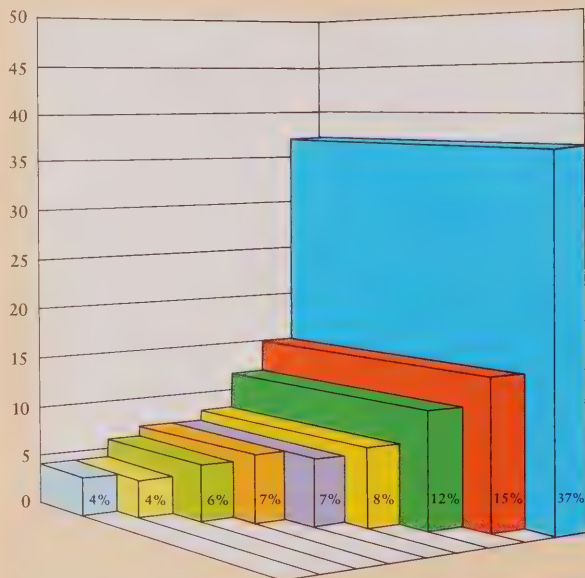
The total of all costs, including those for space, materials and equipment for work done by the Research Division in 1987 was approximately \$57.6 million.

Costs were met or allocated as follows:

Revenue from work done for other organizations	\$ 4.4 M
Transfers to other Ontario Hydro Branches	\$27.5 M
Transfers to the Cost of Power	\$25.7 M

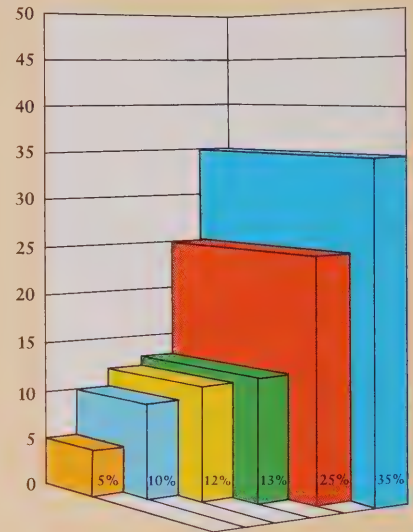
Research Division Programs for 1987 –
Proportions by Actual Gross Costs

- General Research Programs
- Utilization
- Electric Power Systems
- Transmission Systems
- Distribution Systems
- Nuclear Generation
- Nuclear Waste
- Thermal and Hydraulic Generation
- Environmental



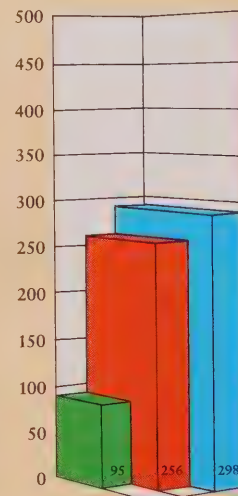
Proportions of Total Salary Costs for
Various Categories of Work

- Testing
- Consultation
- Technical Investigation
- Research & Development, Present Needs
- Research & Development, Future Needs
- General



Occupational Classification of
Research Division Staff

- Management & Professional
- Technicians & Technologists
- Support Staff



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"Modelling Aspects of the Rewetting of Horizontal Tubes", Second Workshop on Advanced CANDU Reactor Thermalhydraulics, October 1987, Hamilton, Ontario.

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Anderson, H.L., and Forest, J.W.

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Anyas-Weiss, N.

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Arora, H.S.*: see Dayal, R. *et al.*

Arron, G.P.

"Effect of Trunk Injection of Growth Regulators on Silver Maple - Second Year Data", Second Annual Tree Growth Regulator Symposium, March 9-12, 1987, Destin, Florida.

A:h, P.O.: see Chan, H.T. *et al.*

Azizian, H., and Braun, J.M.

"Gas-in-Oil Analysis as an Acceptance Criterion during Transformer Factory Overload Testing", CEA Engineering and Operating Division Meeting, March 23-24, 1987, Vancouver, British Columbia.

"Analysis of Trace Byproducts from Overheated Paper Insulation in Power Transformers", CEA Engineering and Operating Division Meeting, March 23-24, 1987, Vancouver, British Columbia.

Balboa, I., Chu, F.Y., Greening, F., Mannik, L., and Mayer, P.

"Characterization of High Temperature Superconductor $\text{YBa}_2\text{Cu}_3\text{O}_7$ and $\text{SmBa}_2\text{Cu}_3\text{O}_7$ ", University of Western Ontario Workshop on High Temperature Superconductor, September 11, 1987, London, Ontario.

Bellamy, G., Nashid, M.S., and Amm, D.E.

"Failure of Hardware on a key 345 kV Span Across the St. Clair River", CEA Engineering and Operating Division Meeting, March 23-24, 1987, Vancouver, British Columbia.

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"Comparison of Hole Drilling Residual Stress Analysis Techniques", Society of Experimental Mechanics Spring Conference, Houston, Texas.

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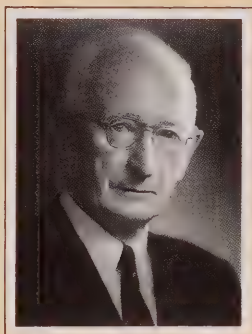
*denotes other than Ontario Hydro employee

SEVENTY~FIVE YEARS OF RESEARCH AT ONTARIO HYDRO

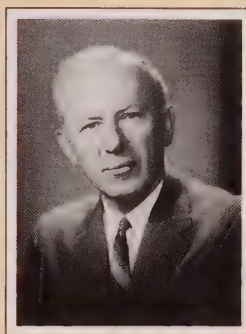
GEN. H.D.G. CRERAR
Chief Testing Engineer
1912-1914



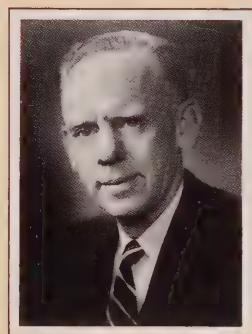
W.P. DOBSON
Director of Research
1914-1953



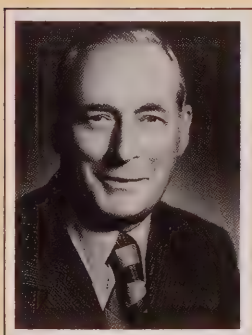
G.B. TEBO
Director of Research
1953-1957



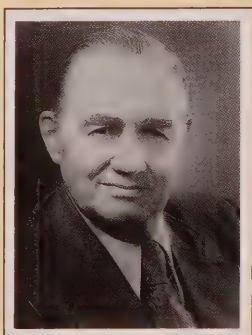
H.C. ROSS
Director of Research
1957-1967



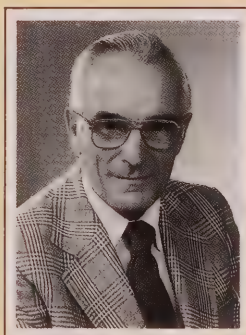
DIRECTORS OF ONTARIO HYDRO'S RESEARCH AND DEVELOPMENT ACTIVITIES 1912-1987



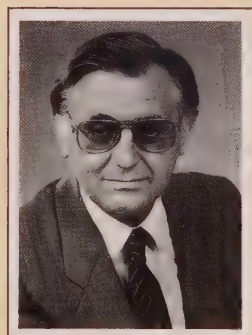
J.H. WAGHORNE
Director of Research
1967-1976



F.J. SIMPSON
Director of Research
1976-1981



F.J. KEE
Director of Research
1981-1986



D. MILLS
Director of Research
1986-



FOREWORD

From a small beginning seventy-five years ago, the Research Division has grown to become a vital part of Ontario Hydro, continually striving towards the goal of better electrical service. We are proud of the contribution made by the Division to the efficient operation of Ontario Hydro and to the electrical and allied industries generally.

To mark the occasion of our 75th anniversary, this booklet has been prepared to provide readers with some insight into the nature and scope of the Division's current responsibilities and activities, a look at significant events and achievements of the past, and a glimpse of the future.

Should a reading of this booklet bring to mind some questions related to the work, inquiries for further details on any project will be welcomed, and will be answered as adequately as available information permits.

D. (Don) Mills
Director of Research

THE RESEARCH DIVISION

A pioneer in electric utility research in North America, the Research Division of Ontario Hydro has, from a modest beginning in 1912, grown to a laboratory with over 650 employees, and attained a leading position in a number of technical fields. Our objective has been to ensure that the most advanced and preferred engineering practices, consistent with sound economy, are applied throughout the power system, and that technical improvements are continually made.

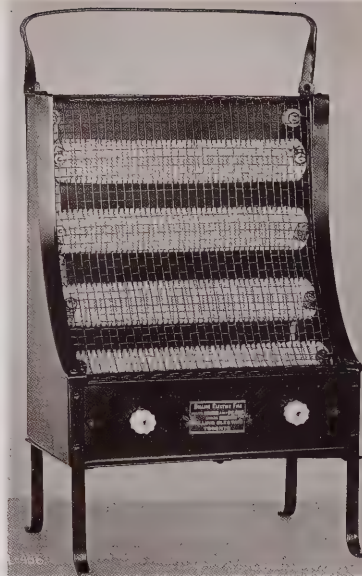
Ontario Hydro, then known as the Hydro-Electric Power Commission of Ontario, was established by an Act of the Ontario Legislature in 1906 to generate and transmit electric power to municipalities in the province at cost. Adam Beck was appointed chairman

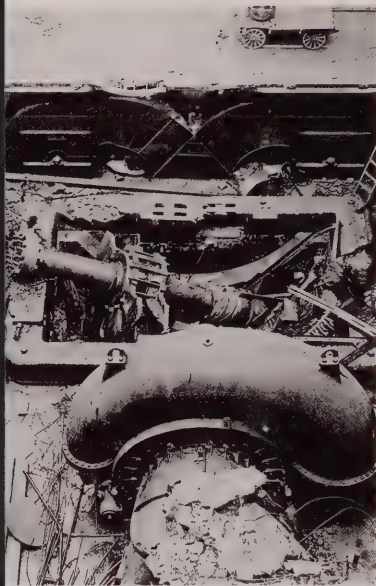


(top left) The first step towards organizing a testing department within Ontario Hydro was taken in 1912, when H.D.G. Crerar set up a one-bench workshop in a corner of the basement of the former Toronto-Strachan Transformer Station. Mr. Crerar, seated in the middle of the lower step among a group of employees, was succeeded by W.P. Dobson, well-known at the time for his studies of transients due to high-voltage switching.

(top right) Portable electric heaters, furnace blowers and kitchen appliances were among a broad range of electrical products that since 1919 had come under close scrutiny of, and performance and safety testing by, Ontario Hydro's approvals laboratory before their certification for sale to the public. After reaching status as a national service, Ontario Hydro's approvals testing function was transferred to the Canadian Standards Association. The service continues to be a large part of CSA's activity.

(bottom) Considered to be one of the most advanced of its type anywhere, Ontario Hydro's structural materials laboratory, part of which is shown here as it appeared about 1920, has been used for all classes of physical testing and investigation of cements, aggregates and other concreting materials. By the end of the '20s, the laboratory had become internationally recognized for its development and use of scientific methods to assure quality of concrete used in construction of massive structures such as hydraulic dams and powerplant generator halls.





(top right) In this scene from the '20s, hydraulic test engineers are measuring hydraulic-turbine efficiencies at Healey Fall Generating Station using, for the first time in Canada, the Gibson method.

(top left) In 1922, metallurgists and chemical engineers of the Research Division were called upon to assist in the investigation of the cause of a catastrophic metal fatigue failure of a generating unit at the Ontario Power Company's hydro-electric powerplant in Niagara Falls.



(bottom) By 1920, the photometric section of the testing and research laboratories had become well established and was being widely used by manufacturers and large purchasers for tests of the performance of luminaires and other lighting products, and by Ontario Hydro for the establishment of adequate specifications. Here, a seven-foot-diameter integrating sphere is seen in use for measurement of the light output of commercial incandescent luminaires by means of a photometer (l) and control panel (r). The photometric laboratory was transferred to the Canadian Standards Association in the early '70s.



of the Commission. First delivery of power from the Ontario Power Company in Niagara Falls, Ontario, was in 1910 over transmission circuits constructed and owned by the Commission.

Since Ontario Hydro is not only an operating utility, but also largely designs and builds the necessary plant facilities, complex technical problems of a wide variety have arisen as the power system grew over the decades. In many instances the solutions have been based on work performed in the Research Division. This work in turn has produced basic improvements to materials and equipment, many becoming industry standards.

The need for utility-sponsored and utility-directed research in addition to manufacturer-sponsored programs has been shown by our experience to date. We have found that many areas of research and development can in fact only be carried out properly by a utility group. Much of the required research involves study of the power system as a whole rather than of the individual components. Typical examples range from studies of overhead-line vibration, environmental effects, system stability, and lightning and other weather-induced phenomena, to waste disposal and other nuclear-related problems and concerns. Most of the Division's growth in recent years has been needed to address such problems. In 1987 the number and complexity of problems, both current and foreseen, call for even more comprehensive interdisciplinary research programs than heretofore.

The Division's research programs are carried out by discipline-oriented electrical, mechanical, metallurgical, chemical and civil research departments, and by project-oriented teams for larger multi-disciplinary investigations. An operations research group performs studies of corporate-wide interest. Advice and guidance from Ontario Hydro's operating, engineering and marketing divisions are



used by standing research advisory committees in planning for future research.

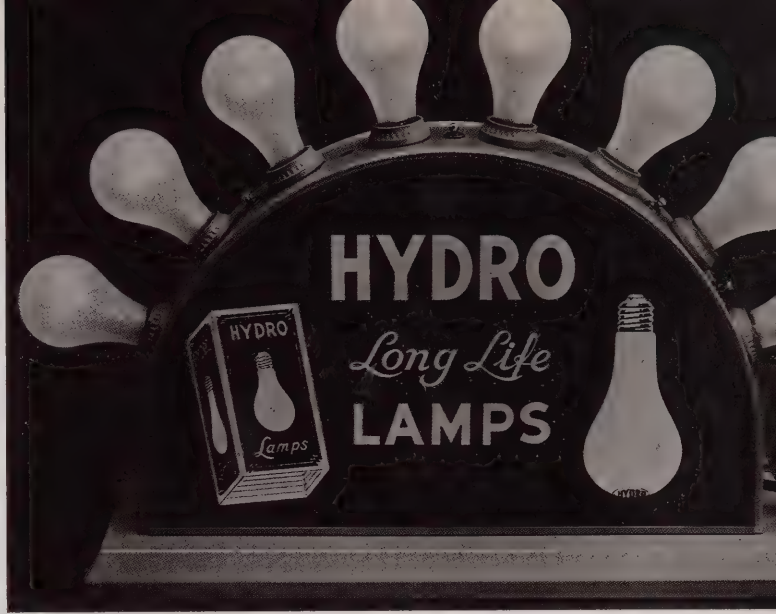
Following a few historical notes, brief descriptions are given of the administrative structure, the general functions and the evolution of facilities of the Division. A description is also given of some significant current activities. Significant events and achievements over the years are represented by selected period photographs that supplement the text.

FROM BEGINNINGS TO PRESENT

Ontario Hydro's research and testing activities had their beginnings in 1912, in the basement of the former Toronto Strachan Transformer Station. As with early construction activities of Ontario Hydro, research and testing began on a small scale. The initial staff of three men began to work on problems of electrical standards and metering and of electric lamp testing and standards. In the following year, the staff of the Testing and Research Department (now the Research Division) was increased to five to enable high-voltage and other electrical testing to be performed. At that time the staff was transferred to a new building constructed next to the transformer station, which, with some additions, housed the research and testing work until late 1961.

As work at the Strachan Avenue laboratories expanded, the organization was divided into four sections: High Tension and General Testing, Standards and Meters, Lamps and Illuminating Engineering, and the Approvals Laboratory.

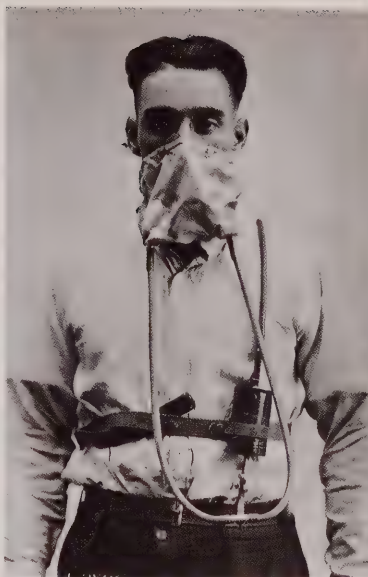
While the principal function of the laboratories was general testing and research, another important one was undertaken in 1919 – the testing of electrical materials, appliances and other equipment for safety from fire and accident. This service was undertaken because of Ontario Hydro's responsibility for the inspection of all electrical installations in Ontario.



(top left) In the '30s, Ontario Hydro launched a campaign to promote good lighting in industry and commerce and in the home. A visual display demonstrates the brightness of "Hydro long-life lamps". These lamps were manufactured to specifications developed by the illuminating section to provide service lives of at least 1,500 hours.

(top right) Over the years, safety in the workplace has been of prime concern to Ontario Hydro. Here, in about 1935, a technician evaluates the efficacy of a respirator designed for use in dusty or otherwise noxious atmospheres. Comparison-testing of various types of breathing apparatus continues to this day.

(bottom) Ontario Hydro was one of the first power utilities to recognize the role of electronic devices in the operation of a large power system. Among the many devices developed were the linascope for locating faults on transmission and communication circuits, the soniscope for ultrasonically examining the quality of concrete structures and the bolometer for measuring remotely the operating temperature of joints in transmission-line conductors.



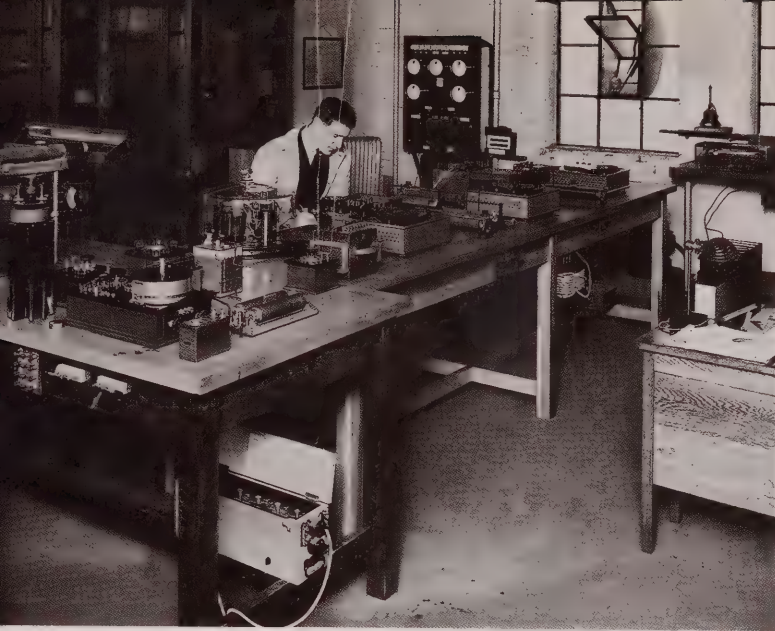


(top left) The petrographer shown here, in the mid-'50s, records her findings after observation of the characteristics and identification of the constituents of a thin specimen of rock through a stereographic microscope. Recommendations of the petrographer largely determine the quality and ultimate endurance of the structure.

(top right) Here, in the '40s, a technician in the electrical standards laboratory calibrates portable standard wattmeters for use in field measurements, against precise laboratory-standard wattmeters.

(bottom) "Waltzing Matilda", the Research Division's mobile high-voltage laboratory of second-world-war vintage, contributed greatly to research in the '50s and '60s on the performance characteristics of apparatus insulation under field operating conditions. Here, "she" is subjecting a spare standby circuit breaker at a transformer station to an insulation power-factor test to ensure readiness of the breaker for emergency use.





The service marked the beginning of electrical approvals and safety testing in Canada. From 1919, it gradually extended to other provinces and ultimately became a national service. In 1950 it was turned over to the Canadian Standards Association.

In 1930, director of research Mr. Dobson said, "In order that the laboratory may be posted on various aspects of testing and research, its members must have special knowledge. This is obtained either by research work and study, or by contact with other engineers engaged in similar work. The most satisfactory way of obtaining progress is by membership on standardizing and other technical committees." Mr. Dobson encouraged his staff to attach themselves to various technical organizations. The laboratory therefore became represented on committees of such bodies as the American Society for Testing Materials, the Canadian Engineering Standards Association, the American Institute of Electrical Engineers, the National Research Council, and the American Concrete Institute.

After 1930, Mr. Dobson continued to direct his organizational ability to strengthen research assistance to Ontario Hydro operating and engineering divisions and to the municipal utilities. He encouraged research staff to embark on new phases of inspection and testing. His keen interest in the basic sciences was used to encourage full use of the facilities of the laboratory.

By the late 50's, because of the increasing volume of work and of changing requirements, the need for more space and better accommodation for the Research Division had become urgent. With abandonment of the Strachan Avenue building required because of its location on the proposed route of a major expressway, plans for the present building on Kipling Avenue were begun in 1959. Construction was started in April, 1960, and the building was occupied in September, 1961.



Since then the main Kipling Avenue building has been supplemented by adjacent buildings used for biological, atmospheric and electrotechnologies research, testing of nuclear-process components, high-voltage and high-current research and testing, mechanical testing and development and other specialized purposes. The Research Division now has altogether about 35,000 square metres of office and laboratory space.

An outdoor laboratory at Kleinburg, about 30 kilometres north of the main laboratory, provides for electrical and mechanical testing of full-scale transmission structures and equipment.

ADMINISTRATIVE ORGANIZATION – THEN AND NOW!

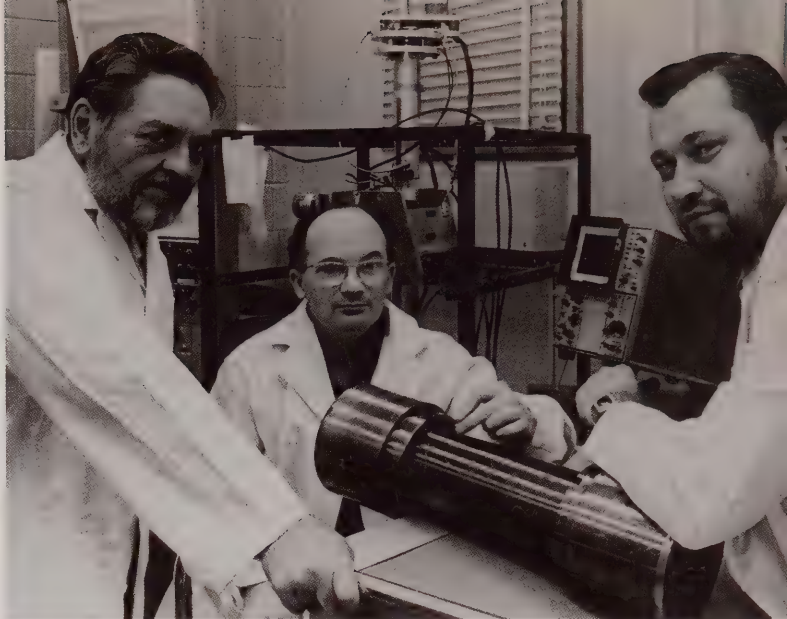
In its early days, the Division was directed by the Chief Testing Engineer with the advice of a Research Committee consisting of himself and the department heads. Subcommittees were appointed to oversee specific areas of research. Today, a similar system exists. The division is managed by the Director of Research with advice from an executive committee of managers. This committee develops research strategy using input from Research Program Advisory Committees of senior researchers appointed to recommend future programs.

Also in place is a technical ladder whereby scientific and engineering experts pursue anticipatory research unencumbered by administrative studies.

Thus the Division's organization is designed and the work coordinated to meet the constantly changing needs of all phases of Ontario Hydro's technical operations.

IN CONCLUSION

Over the past eight decades, Ontario Hydro has pioneered in many ways in the electric utility field. Seventy-five



(top left) Work in the area of nuclear technology involves development of nondestructive on-line techniques and inspection devices for testing of the structural integrity of pressure tubes and other internal reactor components. Here, research staff display a test piece and, in the background, automated ultrasonic equipment, used to appraise various designs of experimental rolled joints at the interface between reactor pressure tubes and the reactor tubesheet.

(top right) In the '60s, a grounded cage surrounding a short length of overhead-line conductor made possible the study of corona phenomena in the laboratory at voltages much lower than actual line operating voltages. This and other test arrangements aided considerably in the development of methods for limiting radio and television interference (noise) from the power system.

(bottom) In 1919, Dr. W.P. Dobson was appointed to the Canadian Electrical Code Subcommittee. At that time the Committees, formed within the jurisdiction of the Canadian Engineering Standards Association (now Canadian Standards Association), were attempting to formulate rules and regulations regarding the inspection and installation of electrical equipment. To him can be attributed a great measure of initiative and success in the development of the Canadian Electrical Code, Parts I and II, and in the inauguration and steady progress of the CSA Approvals Service.

Dr. Dobson continued his interest in the Approvals Laboratories and provided technical guidance in numerous topics for 35 years. The Approvals Laboratories were completely divorced from Ontario Hydro in 1950. Dr. Dobson was honoured by being asked to turn the first sod of the new CSA Approvals Laboratory building aboard a caterpillar tractor on February 23, 1954.



years of related research has contributed to many technical advances.

Much valuable research has been and is, of course, conducted by manufacturers, and in university and other laboratories. The research group of an electric utility such as Ontario Hydro has the advantage, however, of an intimate knowledge of problems that arise in the day-to-day operation of a power system. This aids materially in achieving practical solutions and in confirming their adequacy.

The Research Division now spends about \$60 million on research and development annually. In recent decades, a large part of annual expenditures has been for studies related to the security, efficiency and environmental impact of the Corporation's nuclear generating stations which supply an increasing proportion of Ontario's demand for electricity. Major areas of research are concerned with the safe handling, storage and disposal of nuclear wastes, the integrity and dimensional stability of CANDU reactor fuel channels, the causes and control of corrosion and wear, the development of improved inspection techniques, and the decontamination of nuclear reactor systems. Work is continuing in support of the recently constructed tritium removal facility at Darlington nuclear generating station and of development of tritium technology for the Canadian Fusion Fuels Technology Program.

Other research deals with new and improved electrotechnologies for efficient use of electricity. Techniques are being developed that will permit more effective use of generating units, transmission lines, underground cables and interconnections with other systems. New developments also include upgrading of the capabilities of transmission lines and substations and automation of the distribution system.

Research continues into the formation of acid rain and development of measures for the control of acidic emissions from coal-fired generating



stations. Systems for the diversion of fish to avoid blocking of generating station water intakes are being developed, tested and implemented. A process developed for treatment of PCB-contaminated insulating oil and its restoration to oil of reusable quality has been successfully demonstrated to regulatory authorities and put into service.

In most projects, Ontario Hydro cooperates closely with other electric utilities, the Canadian Electrical Association, the Electric Power Research Institute in the United States, and manufacturers of equipment and materials. About 10 percent of the Research Division's effort currently is funded through contracts with these and other external agencies. The results often lead to transfer of technical expertise to the manufacturing sector.

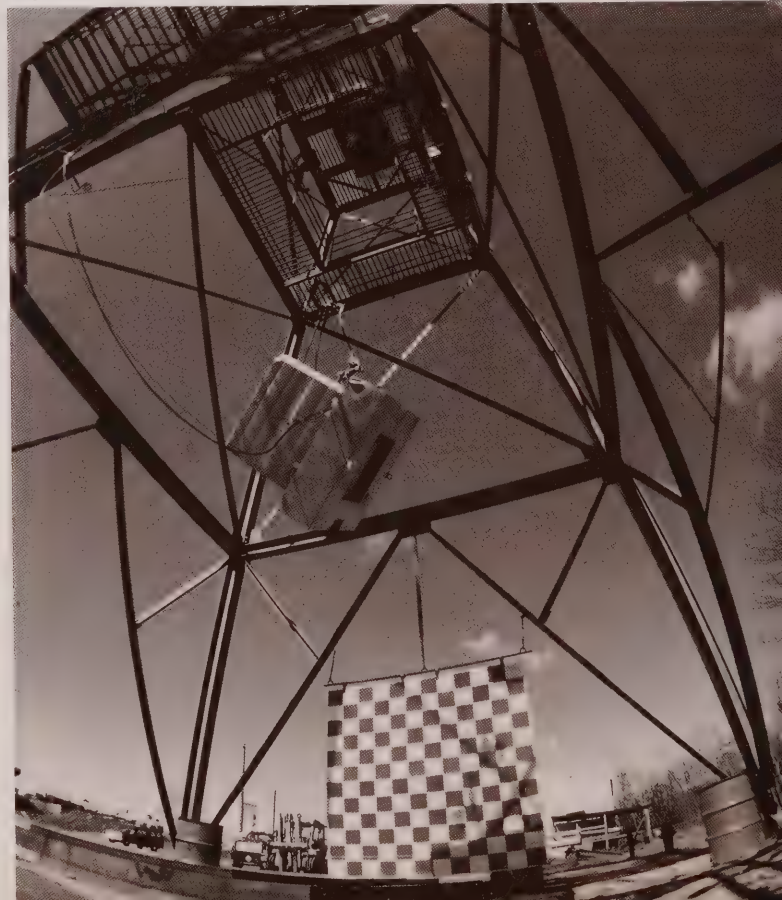
With continuing growth in the use of electricity and increasing technological and social demands, a challenge of immense proportions faces Ontario Hydro in the years ahead. As in the past, the Research Division's aim for the future will be to continue to provide technical services of the highest possible standard. Hydro's research, furthered by modern laboratory facilities, will assist substantially in providing a dependable and economical supply of electric power to users throughout the province.



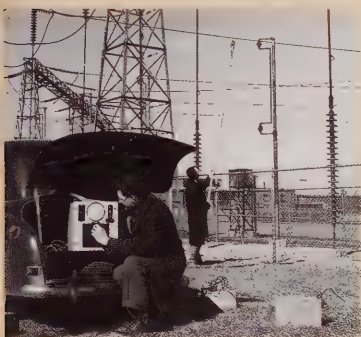
The technology available for analysis of materials has advanced phenomenally from the '50s to the present. Today, elemental composition analyses and high-resolution imaging of materials support of metallographic, biological, geological, and other studies, are performed on a scanning electron microscope supplemented by an x-ray diffraction analyzer.

Much of the Research Division's nuclear work involves the study of means for safe handling, interim storage and permanent disposal of irradiated materials produced during the course of operation of Ontario Hydro's nuclear generating stations.

Here, at the Chalk River Nuclear Laboratories of Atomic Energy Canada Limited, the integrity of a stainless steel container for transportation of irradiated fuel was demonstrated in a free-fall drop test of the cask from a height of nine metres onto an unyielding surface.



Some Significant Research Contributions Over The Past 75 Years



The Linascope – a device developed to locate faults in transmission and communication circuits.



The tri-axial shaker – an instrument developed to seismically qualify small- and medium-size nuclear equipment.



Flyash Utilization – an early leader in the application of flyash as a pumping aid in the placement of concrete at Ontario Hydro's nuclear sites.



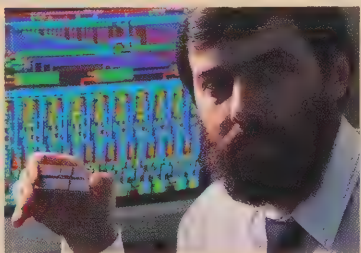
The Soniscope – an ultrasonic device developed to measure deterioration and cracking in concrete.



The Coronaphone – a device designed to locate sources of radio interference due to corona discharge on high-voltage lines.



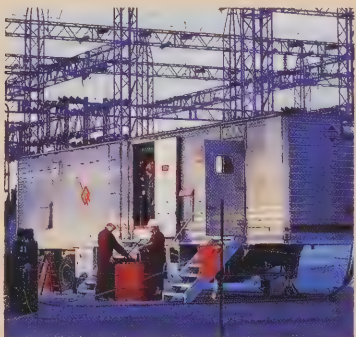
Monitoring for Predictive Maintenance – a computer-managed system developed for use in planning hydraulic generator maintenance.



ASIC – an Application Specific Integrated Circuit chip developed to replace existing digital circuits or to be used in new applications with specific requirements.



The Bolometer – an infrared instrument developed to detect overheated transmission line joints.



The Mobile Processing Unit – an oil processing facility designed to destroy low-levels of polychlorinated biphenyls (PCBs) in insulating oils safely and effectively.

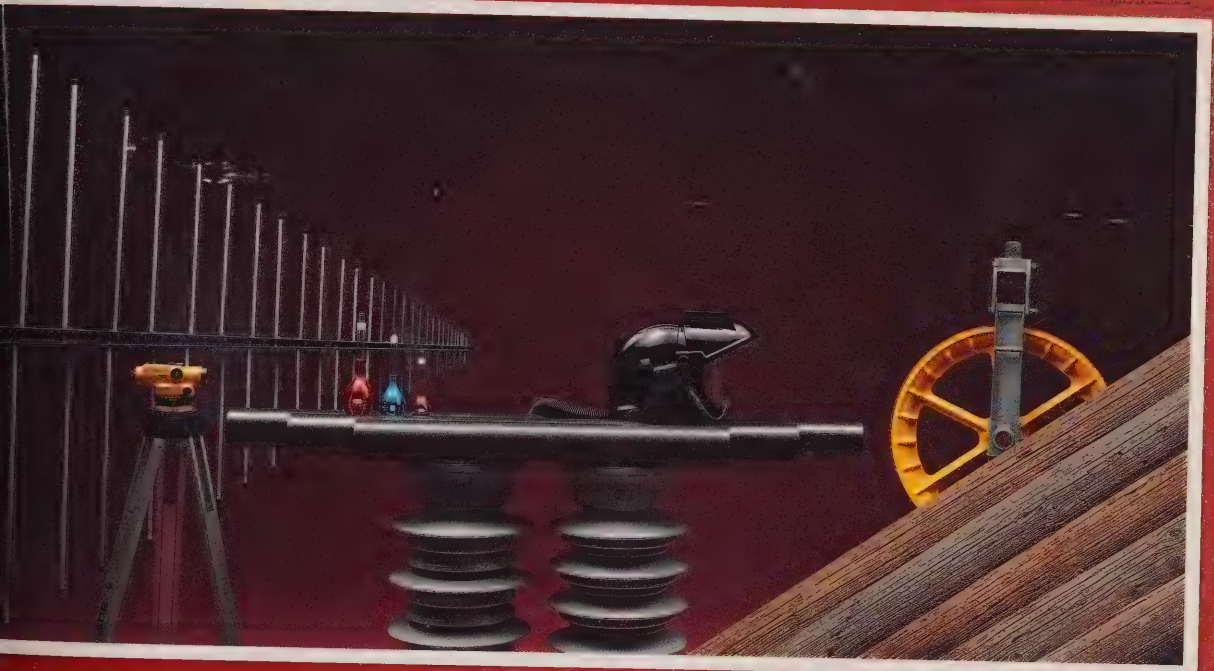


CIGAR – a Channel Inspection and Gauging Apparatus developed to measure the dimensions and evaluate the integrity of pressure tubes in the fuel channels of CANDU reactors.



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Ontario Hydro RESEARCH ANNUAL



Ontario Hydro Research Division Annual Report 1988

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The Research Division's Commitment

Customers: Meeting changing needs

Demand Management: Using energy efficiently

Supply Management: Examining every option

Environment: Minimizing ecological costs

Corporate Management: Meeting employee needs



Lorne McConnell and Bruce Semper, Vice-President of Operations at Davidson Instrument Panel (a subsidiary of Textron Inc.) discuss the use of microwave heating to help solve a hazardous waste problem.

Ontario Hydro's highest priority has always been to provide its customers with products and services synonymous with the highest possible value. To help meet this goal, in May of 1988, a new Corporate Strategy was approved by Hydro's Board of Directors. The new strategy will shape Hydro's operating environment for the foreseeable future. The critical challenge the Corporation faces is to implement this strategy without losing sight of society's evolving attitudes and expectations. In a context hallmarked by change, Ontario Hydro must commit itself to innovation, continuing, at the same time, to build on its traditional strength as a supplier of efficient, safe, and relatively inexpensive electrical power.

The renewed Corporate emphasis on innovation and efficiency and its commitment to dealing with environmental issues have served only to reinforce directions already being pursued by the Research Division. Promoting customer awareness of efficient use of energy and responding quickly to customer requests for advice and assistance are important parts of the Research Division's mandate. Equally important is the Division's role in helping the Corporation ensure the Province of Ontario that the Corporation's facilities and activities are environmentally sound.

Considered as a pioneer in the field of environmental research, the Research Division continues a comprehensive acid rain research program while, more recently, it has focused close attention on studies related to the so-called "greenhouse" effect. More so than any other issue, the implications of this effect are considered to have the ability to impact on the environment on a global scale.

The Research Division's awareness of emerging environmental issues has caused no decline in the pursuit of technologies allowing the provision of the greatest net benefit to Ontario Hydro's industrial customers. By continuing to conduct high quality research and development, by helping customers make the best use of electrical power, and by disseminating knowledge enabling Ontario's manufacturers to improve the quality of their products, the Research Division has helped to forge and assure Ontario Hydro's role as a leader in the energy field.

L. G. McConnell

L. G. McConnell
Vice-President
Power System Programs



Don Mills and Lew Hutchinson, President and CEO of LASCO, discuss electric arc furnace technology, a major interest of Ontario Hydro for which a research facility has been developed at Lakeview.

The mission of the Research Division is to provide Ontario Hydro with the scientific knowledge and technology needed to solve the problems of today and to anticipate those of tomorrow. As Hydro is faced by an ever widening range of technologies, both traditional and new, decision making that remains viable and applicable in the future becomes increasingly difficult. It is fortunate then that research by its nature is open ended: it does not neglect the proven nor does it falter its ongoing search for the possible. The Research Division has a very real role to play in helping Ontario Hydro implement its new Strategy intended as a means of dealing with economic and technological change.

Many of the initiatives undertaken at the Research Division in support of Corporate Strategy are already in place. The need to promote customer awareness of efficient use of electricity and to respond quickly to customer requests for advice and assistance has been a high priority for some considerable time. One benefactor is Ontario industry, and product and process evaluations are conducted in close cooperation with industrial customers. Another is the residential sector. Residential energy efficiency potential is being aggressively explored. The ultimate result will be an increase in the health, wealth, and comfort of Ontario Hydro's residential customers as well as an increase in the Corporation's control over demands made on the bulk electricity system and local distribution networks.

Equally important to reducing power demand is sustaining a reliable supply management program. One important aspect of this program is the need to focus attention on existing generation, transmission, and distribution facilities. To meet one aspect of this need, the Research Division has committed a major component of its resources to the Corporation's extensive life assessment program that will assure the continued safe, reliable, and economic operation of existing plant, be it thermal, hydraulic, or nuclear.

In its pursuit of the scientific knowledge and technology needed to meet the challenges that the Corporation faces as it prepares for the next century, the Research Division is always aware that the environment cannot be traded off for the sake of progress: it commits to design and to carry out its research and development plans in a way that ensures that environmental concerns are addressed. Guided by Corporate Strategy, effective planning within the Division will continue to build in the flexibility needed to meet the needs of a variety of circumstance. Customer satisfaction, reliable supply, and reasonable cost will be the criteria for making decisions that are environmentally sound, technically reliable, and financially feasible.

D. Mills
Director
Research Division

Helping Ontario Hydro Manage Change

Ontario's citizens want more than efficient, safe, and reliable electrical power supplied at reasonable cost. A more sophisticated public increasingly views the provision of electrical power as a service like any other to be judged on the basis of value added, not on the basis of price alone. A major concern is the environment, which cannot be seen as something to be traded off for the sake of progress. As Ontario Hydro's Chairman and President, Robert Franklin, puts it, the condition of the "environment is a measure of society's standard of living, rather than a good to be bartered or compromised for technological achievement".

It was against this backdrop of public concern, coupled with an appreciation of how macroeconomic trends and new technologies are revolutionizing the economy and the industrial structure, that Ontario Hydro revised its Corporate Strategy. Reflecting changes in customer expectations and the society it serves, the Strategy will guide the Corporation in its business activities through to the end of the century.

The Strategy focuses on five key areas, which are customers, demand management, supply management, the environment, and corporate management. The Research Division is strongly committed to this Strategy and what follows is an account of some initiatives undertaken in support of it.

For Ontario Hydro, the provision of the greatest net benefit to its customers, both collectively and individually, and the pursuit of economic demand management options consistent with Government policy are highly interrelated. And, in 1984, when forecasts indicated a possible shortage of generating capacity in the 1990s, planning to meet increased needs resumed. Since then, considerable effort has been put into developing new approaches to help customers reduce their electricity costs without harm to the environment. The Process Metallurgy Project, a new Research and Development (R & D) activity conceived within the Divisional Projects Department and nurtured by the Metallurgical Department, is one which, while meeting the needs of Ontario Hydro's customers, impacts significantly on both demand management and on environmental concerns.

The Process Metallurgy Project signals a radical departure from the type of work that has historically been undertaken by the Metallurgical Research Department. Rather than being concerned only with the enhancement of materials, components, and processes used for the generation of electricity, the project is aimed at improving the efficiency of energy utilization while assisting in the development of new

production technologies. The objective is to allow Ontario metal producers to maintain a competitive edge.

An electric arc furnace was established to serve as R & D facility in support of Ontario's metal smelters and melters. Built into the design of the facility is a great deal of flexibility intended to meet the needs of the diverse applications of electric furnaces in the many different segments of the metallurgical industry.

The first project to use this facility is one being undertaken in cooperation with Falconbridge Ltd., a company required by law to bring its sulphur dioxide emissions in line with the requirements of the Provincial Government. Several approaches were under study at Falconbridge. However, what appeared to be the best approach to the problem was found to increase energy consumption. As a response, Ontario Hydro furnace will be used to examine other ways of dealing with the problem. The process finally selected must help minimize operating costs, thereby allowing Falconbridge to maintain its competitive edge.

The renewed Corporate emphasis on efficiency and cost reduction has reinforced an already established direction for the Research Division. The Utilization Section of the Electrical Research Department is actively playing the role of facilitator, consultant, researcher, and educator in the development of a number of new electrotechnologies.

Using waste heat from one process as input to another is an efficient and cost effective use of resources. Heat pump technology can be utilized to recover heat from air or water flows. To further enhance efficiency, off-peak thermal storage can be implemented to complement the job. Following the successful demonstration of this type of technology in the restaurant industry, a new project at Ontario Hydro's Orangeville Conference and Development Centre is well underway. Waste heat from the dryer exhaust of the Centre will be used to heat wash water. A concomitant benefit is an improved working environment achieved through space cooling and dehumidification. Power demand reduction and energy savings of 40 to 50 percent are anticipated.

In the Corporate Strategy document, the need to promote customer awareness of efficient use of electricity and to respond quickly to their requests for advice and assistance is stressed. The Research Division continues to emphasize this important strategic thrust; and tests, evaluations, and demonstrations have been conducted for over 60 Ontario companies this year. Evaluations are conducted in cl

cooperation with industrial customers, and currently, applications ranging from welding of jewellery with lasers to the treating of waste materials with microwaves have been implemented. All applications have one thing in common:

they are intended to achieve the manufacturer's goal of lower production costs and Hydro's goal of reducing demand. Examples of the implementation of such technologies include the successful application of heat pump technology that significantly improved the quality of one food processor's product and that, at the same time, reduced its electricity bill by 64 000 per year; microwave technology that allowed an automotive parts producer to deal with waste materials, thereby reducing both his space requirements and his labour costs; and the installation of a dehumidifier that allowed a ceramics company to expand because of increased quality and productivity.

Work on power demand reduction is not confined to the industrial sector. Residential energy efficiency potential is being explored. There are 370 000 electrically heated homes in Ontario, representing a winter peak demand of almost 4 000 megawatts. The challenge provided by a cold climate is to increase energy savings while decreasing indoor air pollutant concentrations. A survey of 1000 electrically heated homes is underway to determine the potential for demand reduction and energy savings by using thermal envelope upgrading, energy efficient appliances, and advanced window technologies. Even a modest penetration of such technologies into the existing market could provide more strategic conservation than any other single option. The ultimate result will be an increase in the health, wealth, and comfort of Ontario Hydro's residential customers, as well as more control over the demands made on the bulk electricity system and local distribution networks.

Although demand management is the option of choice in Hydro's efforts to meet customer needs in a responsive way, Corporate Strategy pays considerable attention to the necessity of rehabilitating aging facilities in an orderly and cost effective manner. The Research Division recognizes existing facilities as the most important category of generating plant over the next 20 years and also that rehabilitation of old plant is the more economic alternative to plant shut down.

Experience teaches that the operation of a thermal plant beyond its design life can result in reduced reliability attributable to sudden failure of critical components. But experi-

ence also shows that a large fraction of problems arises from a small fraction of components. Ontario Hydro is thus proceeding with a major program of life assessment.

The Research Division believes that the solution to the

problem of plant aging is the process of "fingerprinting". In this life assessment process, key components of plant are examined for signs of degradation so that continued operation may be assured or, alternatively, needed replacements may be properly planned.

Some years ago, the Research Division initiated a program to upgrade the flexibility and responsiveness of its metallurgical evaluation capability, and this is of great value in the life assessment process. Traditionally, this type of evaluation was destructive in nature, requiring the removal of each component for laboratory testing, microscopic examination, and any other required testing. Now, new capabilities developed at the Research Division allow the preparation of high-resolu-



The eight departments of the Research Division are here represented by their managers. From left to right: T.W. Klym (Civil Research); D.J. Dodd (Chemical Research); N. Anyas-Weiss (Divisional Projects); A.H. Chung (Operations Research); G.J. Clarke (Mechanical Research); J.B. Brown (Divisional Services); A.F. Baljet (Electrical Research); J. Brown (Metallurgical Research).

tion plastic replicas of metallurgical structures.

A key advantage of the nondestructive technique is that it creates a permanent record of a microstructure, which can then be used for comparison when specific areas of concern need to be examined at future times. This new capability can be used in both the laboratory and the field setting, the end result being more reliable plant because of more efficient tracking and assessment of component integrity. The performance of these life assessments alongside the Division's long-term R & D program allows enhanced utilization of resources leading to the increased precision with which repair and replacement decisions can be made.

Like other types of power plants, nuclear stations are susceptible to aging. And because nuclear generation represents the cleanest and, after hydraulic, the second most economic energy source in Ontario Hydro's bulk electricity system, nuclear plant component aging is drawing a great deal of attention. After Darlington is fully in service, nuclear generation will account for about 60 percent of Ontario Hydro's total energy production. Therefore the importance of securing the high performance and safe operation of Ontario Hydro's nuclear stations cannot be emphasized enough.

Within Ontario Hydro, research efforts directed toward ensuring the optimal performance of its nuclear plant are covered by the two components of the Nuclear Plant Life

Assurance (NPLA) Program. One component of the program is committed to assure the life of Ontario Hydro's nuclear plants during the normal service life of 40 years by maintaining their long-term reliability, availability, and safety. The other component concerns life extension, which preserves the option of extending the life of Ontario Hydro's nuclear plant beyond a normal service life of 40 years. These objectives are consistent with the demands of Corporate Strategy, which emphasize that the reliability of Ontario Hydro's existing nuclear facilities will continue to be important in meeting Ontario's electricity requirements beyond the year 2000. The emphasis of the program at present is on life assurance.

A nuclear plant has thousands of components, all of which age with time. The first step in the proposed NPLA methodology is to divide plant components into two categories, critical and noncritical. Noncritical components are those that can be easily and economically replaced and critical ones those that are neither easily nor economically replaced, the failure of which would impact negatively on the safety, reliability, and life expectancy of a plant. Based on specific selection criteria, the list of critical components is prepared and includes components such as fuel channels; steam generators; the calandria vessel, its supports and cooling system; primary and secondary heat transport piping; vacuum building; and cables.

The second phase of the program, "scoping", serves to identify what needs to be done. For each critical component new initiatives required to achieve the following are identified:

1. An understanding of the aging mechanism through an analysis of operating history;
2. A condition assessment;
3. An early detection and prediction of age-related degradation;
4. A slowing down of age-related degradation through utilization of proper operating and maintenance procedures; and finally
5. Restoration of lost performance through repair, refurbishment, and replacement.

The NPLA program is strategically important to Ontario Hydro's future, and although much progress has been made toward understanding and managing the consequences of aging, not all aging-related issues are fully understood. Work still needs to be done in areas such as irradiation embrittlement of metallic components, assessment of concrete aging, and development and validation of "remaining life" prediction models through laboratory and field testing. The Division's R & D effort carried out in support of NPLA is therefore essential. Results of work done by other utilities are undeniably of benefit to Ontario Hydro's program, but, because the CANDU system is unlike any other, Ontario Hydro, along with Atomic Energy of Canada Limited (AECL), must stand virtually alone.

In terms of new supply options, Corporate Strategy demands that preference be given to developing non-utility and any remaining hydraulic sources. In addition to pursuing the development of new economically and environmentally viable locations, Hydro's commitment to existing hydraulic facilities is reflected in the establishment of the Corporate Dam Safety Program. The Research Division, as

part of the interdisciplinary dam safety team, has made a major contribution in its provision of state-of-the-art technical support.

In the decades since Ontario Hydro's water-retaining structures were built, evaluative techniques and equipment have changed. Modern techniques are used to obtain appropriate strength parameters and to probe an existing dam for weaknesses. Advanced in situ testing devices, such as the dilatometer and the piezocone for use in earth dams and the Soniscope for use in concrete dams, can provide detailed information about a dam.

Advanced drilling techniques, automated data acquisition systems, and remote data transmission contribute significantly to the assessment of dam performance. These new developments are vital in providing the information necessary in the planning required to keep hydraulic stations operating safely and reliably. Maintenance and repair needs are also being served by the development of robots that can be used to maintain vital pressure relief systems in previously inaccessible dams.

Ontario Hydro, accepting that no form of energy is environmentally benign, commits to design and execute its development plans in a way that ensures the continued vitality of the ecosystem. Over the years, environmental concerns have grown in complexity, and no longer can an individual agency proceed as if it alone were involved in a search for information. Recognizing the efficacy of sharing expertise, the Division has participated in collaborative environmental research involving networks of industrial, government, and university agencies for over ten years.

The Research Division continues to investigate a number of options for controlling acid-gas emissions, and an acid rain research program involving dry deposition measurements and cloud modelling continues.

Power plants emit nitrogen oxides (NO_x), which are photo-oxidants. Thus, Ontario Hydro is anxious to define the role of NO_x in the formation and behaviour of photo-oxidants, some of which may play a key role in reactions that lead to the formation of acid rain. The work of the Division is currently focused on making measurements of natural NO_x emissions; analyzing air samples for volatile organic compounds; measuring the size distribution and trace element content of atmospheric aerosols; and measuring nitrogen dioxide dry deposition fluxes. Through direct data analysis and the use of mathematical models based on these measurements and the vast amount of data collected by other participants in the study, ozone concentrations in power plant plumes and in air masses that originate in different areas can be determined.

More so than any other environmental issue, the so-called "greenhouse" effect has the potential to impact on the environment on a global scale. Fossil-fuelled power stations emit two "greenhouse" gases, carbon dioxide and nitrous oxide. The emission of these gases is being monitored. Preliminary results indicate that nitrous oxide concentrations are much lower than the literature suggests.

Another "greenhouse" gas, methane, is increasing its concentration in the atmosphere at the unprecedented rate of one percent per year. The reasons why are not clear, but the Division is involved in a recently initiated Canadian Institute for Research in Atmospheric Chemistry (CIRAC) study that aims to determine the role of the vast Northern Wetlands

Canada, which are suspected of being a significant source.

Also of great importance is Ontario Hydro's nuclear waste management program. In 1978, the Corporation entered into a technical assistance program with AECL. Since that time, Design and Development—Generation, Nuclear Generation, and Research Divisions have been collaborating in a work program that has developed significant capabilities in areas of nuclear waste management. As a result of this extensive involvement in the Corporate Program, the Division has developed initiatives in nuclear waste storage, transport, and disposal.

Development of methods of high-level waste transport and extended storage is underway. Road, rail, and barge modes of transport are being evaluated, and a special cask is being developed intended for storage, transport, and disposal of nuclear waste. The objective is to create a container able to withstand shock, vibration, and heat. Studies of dry vault design and determination of the temperature limits at which CANDU fuel bundles can be held under dry storage conditions without loss of integrity are in progress. The focus of this latter endeavour is to provide the data needed to determine suitable disposal sites in geological repositories.

Another major initiative arises from the decommissioning of the Nuclear Project Demonstration (NPD) generating station. The station makes available a major source of concrete that has been subjected to varied thermal and irradiation fields during the normal operation period of the plant. Concrete cores have been retrieved from numerous locations, and now, the effect of radiation as well as high thermal fields on the performance of concrete containment structures can be assessed. This work is highly relevant to the evaluation of cement-based materials as engineered barriers for controlling the leakage of radionuclides.

The Strategy document points out that the broad trends toward flexibility and innovation must spill over into the management of the Corporation itself. The strategic emphasis is on providing opportunities and challenges to meet employee needs and on being at the leading edge of research and development of selected technologies beneficial to Ontario Hydro's operations. Two examples serve well to illustrate the Research Division's commitment, both to its employees and to the more global needs of the Corporation. These are the dual ladder career system and the Integrated Computing Environment (ICE).

People are Ontario Hydro's most valuable resource, and for an employee to feel challenged and appreciated, it is often necessary to create a working environment that meets individual needs. In 1986, with these needs in mind, the Division initiated a technical ladder system. The system is flexible, recognizing those Research Division staff who have consistently made outstanding contributions in the technical sphere. On the one hand, Research Division personnel have been able to make their way, traditionally, by promotion up the managerial rungs of unit head, section head, department manager, and director. On the other, nontraditionally, staff now may climb the technical ladder, starting with an entry level position and progressing through more senior levels to the positions of Senior Research Scientist or Engineer and Principal Engineer or Scientist. The latter two positions are equivalent to the section head and manager positions both in status and remuneration.

In a world hallmarked by change, the technical ladder

serves the strategic needs of the Corporation especially well. The advent of the CANDU reactor brought with it a whole set of new research questions and a much greater public awareness of environmental issues. Additionally, the amount of relevant research being done elsewhere is increasing dramatically, both nationally and internationally. The strong scientific reputation of employees on the technical ladder allows broad access to new information generated by peers in other research facilities. An additional benefit of the technical ladder is that the senior ranks on the technical ladder have access to, and can influence, the same decision-making bodies as their counterparts on the managerial ladder. The result is enhanced communication that makes it possible for the Research Division to exert a great deal of influence both inside the Corporation and in the scientific community at large.

Enhanced communication was also at the heart of the proposal for the implementation of ICE, a project designed to link researchers by linking computers and other electronic equipment throughout the Division and beyond. Like other Divisions faced with the problem of limited financial resources and the need to make sizable investments in computing resources, the Research Division had to assess how best to take advantage of emerging technology to enhance the capabilities of researchers and at the same time to facilitate the overall administrative effectiveness of the Division. Because controlling costs, managing change, making the most effective use of Corporate resources, and taking advantage of new opportunities faster and more effectively all require the optimal handling of information, a project like ICE seemed both timely and relevant.

Essentially, ICE will provide a data communication system similar to those already implemented in other parts of the Corporation. The benefits of such systems are enormous. The project is cost effective: it allows the sharing of expensive hardware and software, which in turn can be shared by many users. The project impacts on the Corporation's business needs: by implementing a far-reaching and compatible network, a business culture can be unified while, at the same time, its complexity can be reduced. ICE will improve the quality of the working life of the Division's employees: the system will aid in the organization and handling of a steadily increasing amount of data, thereby reducing the work load during the yearly planning cycle. ICE allows wider access to the Corporation at large: the delivery of critical data and expertise to and from the Research Division will be vastly improved, thereby benefitting situations of Corporate importance. ICE will allow the Division the opportunity to participate in, and exchange information with, the research community at large: it allows global access to information about current developments in high-interest areas.

The Division's vital role in helping Ontario Hydro effectively manage change in a future that remains uncertain will continue. Guided by the Strategy document, effective planning within the Division will serve to build in the flexibility needed to meet the needs of a variety of circumstances. The principles of customer satisfaction, reliable supply, and low customer cost will be emphasized. In a time frame that is rapidly shrinking, the choices resulting from R & D will have to be environmentally sound, technically reliable, and financially feasible.

Dealing Responsibly with Environmental Issues

The Chemical Research Department is a technical resource that provides support to the Corporation in the areas of process and materials chemistry, chemical analysis, biology, and environmental science. A staff of about 140 chemists, chemical engineers, biologists, and highly skilled technicians work on a research and development program involving scientific research, technical investigation, and problem solving. Comprehensive analytical and testing services are also provided by the Department.

The research capabilities of the Department were enhanced in 1988 by the acquisition of thermographic and x-ray equipment and associated image enhancement apparatus for the development of expertise in the non-destructive evaluation of non-metallic materials. Analytical capability was increased with the addition of an inductively coupled plasma (ICP) arc spectrophotometer and new mass spectrometer equipment.

Almost one-third of the Department's resources are invested in support of the Corporation's nuclear commitment. This work is wide in scope, ranging from research dealing with nuclear waste management options to modelling the potential spread of contaminants after a simulated loss of coolant accident. A significant effort in support of nuclear generation deals with maintaining steam generator tube integrity.

Degradation of steam generator tubes, which may result in leaks of primary coolant, is a major concern in the operation of nuclear plants. Although Ontario Hydro's



CANDU reactors have been world leaders in steam generator integrity, a long-term research program is being carried out to anticipate problems that may occur and to develop remedial measures to avoid or minimize their consequences. Emphasis in 1988 was on the introduction of field studies of the condensate, feedwater, and steam generator water chemistry. The major objective of the chemistry control program is to minimize the rate of ingress of impurities into the steam generators. Transport studies to determine the sources of corrosion products in the secondary circuit during steady operation and during system transients, such as start-up, shut-down, and load-following, have been done.

At Pickering NGS, sampling has been started to determine morpholine levels in the various units and to monitor the concentrations and distributions of its decomposition products. Additionally, the impurities released to the bulk water during unit shut-down have been studied. The result is a better understanding of the chemistry in the crevice region during operation. This shift in emphasis from the laboratory to the field should result in immediate benefit to the station in that secondary system chemistry will be optimized.

Also at Pickering, during the major retubing operation that started in 1985, work in Units 1 and 2 was impeded by unexpected contamination from carbon-14 in the form of easily dispersed fine black dust. Research studies show this to be a carbon-nitrogen polymer. Further research established that oxidation of the carbon-14 could reduce possible contamination during the retubing of Units 3 and 4. Sub-



quent trials of oxygen introduction into Unit 4 showed that oxidation rates were enhanced by radiolysis; however, complete system decontamination could take considerable time. Therefore on-power oxidation will be combined with a continuous on-line $^{14}\text{CO}_2$ capture system developed by the Chemical Research Department and modified for installation on the Units 3 and 4 annulus gas systems. This removal system will be installed on Pickering Unit 3 before the end of 1988, and long-term oxygen-injection tests with $^{14}\text{CO}_2$ monitoring will be undertaken.

The reactor waste management research program undertook characterization of the different waste streams in terms of their chemical and physical composition, activity level, and radionuclide inventory. Knowledge of these waste characteristics is of use to both Design and Operations Divisions. It allows the determination of processing equipment and storage structure requirements and the establishment of the hazard levels of various wastes and the time it takes for them to decay to a non-active status. Additionally, the knowledge allows the determination of the radioactive inventory in storage and the determination of any special disposal precautions that might be required.

Techniques to immobilize and package tritiated wastes for storage and disposal were studied. The wastes that could come from the Darlington Tritium Removal Facility include waste water, oil, and metallic components. Once conditioned by immobilization, the amount of tritium released daily by leaching should be less than 0.001 percent of the

initial amount, and the waste package should retain its integrity for 150 years. The research showed that immobilization alone could not retain the tritium adequately, but that the use of 1-cm thick high-density polyethylene containers gave more than adequate retention of tritium and, being corrosion resistant, should provide the desired containment life.

Research studies in the Environmental Program area range from monitoring the effects of Ontario Hydro's operations on ecosystems and assessing the impact of environmental changes on its activities, through meeting new regulations for air and water quality, to developing means of controlling environmental emissions.

To improve the ongoing aquatic surveys at generating facilities, more efficient sampling techniques are being developed. Emphasis is being placed on non-consumptive and remote sampling systems. Options such as radiotelemetry and acoustic sampling are being actively pursued and are expected to figure prominently in studies of fish populations and their movements. Enhancements to existing sonar systems coupled with the application of artificial intelligence concepts have provided encouraging laboratory results. In the future, the ability to distinguish fish from debris by means of sonar techniques, and even to differentiate between species of fish, appears promising. If successful, the expected application of these techniques will make future surveys more effective, environmentally more acceptable, and less costly.



Sampling is being carried out as part of the containment integrity studies at Darlington NGS. Ethylene and helium gases are used to simulate hydrogen gas, thereby giving insight into accident conditions.

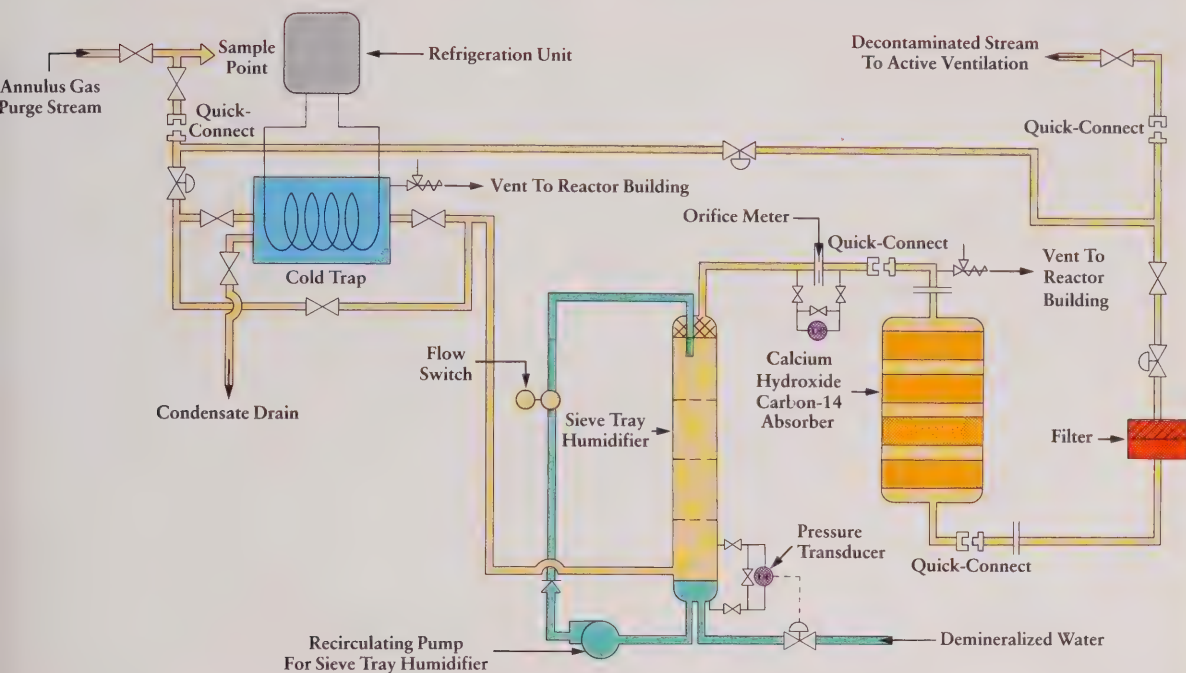
During 1988, work in the environmental emissions area concentrated on the reduction of acid-gas precursors. A more extensive account of some of the Department's activities in the environmental area is to be found in the earlier article concerning the Division's contribution to Corporate Strategy.

A program to develop the furnace limestone injection process for reduction of SO_2 emissions from coal fired plants yielded results that could lead to a low-cost process for control of NO_x emissions. In the conventional limestone injection process, it is known that wetting the material downstream of the furnace improves both the efficiency of SO_2 removal and the capture of waste in the electrostatic precipitators. Now, studies of the injection of limestone directly into the furnace in the form of a slurry, which contains a special reducing agent that reacts with NO to produce N_2 , show not only up to 70 percent SO_2 capture, but also up to a 90 percent reduction of NO_x emissions. If further pilot-scale and full-scale tests are equally successful, this process could provide a high-efficiency NO_x -control option many times less expensive than currently available technologies.

The reliability of Ontario Hydro's 500-kV transmission

system under icing conditions is of considerable concern. Over the last few years, a number of flashovers have occurred, the most serious in March 1986, when the system was shut down during conditions of fog at sub-zero temperatures and during rising temperatures. The mechanism of ice formation under these conditions was investigated in the laboratory at the University of Quebec. A parallel study of the environmental conditions associated with flashover events was carried out in the Chemical Research Department.

The University of Quebec study demonstrated that the increased water conductivity on the surface of icicles and melt water decreased as melting progressed. The Chemical Department's related environmental study involved the sampling of a number of fogs and the subsequent determination of their chemical composition and conductivity. Frequently very high conductivities were found. These data suggest that fog may be an effective medium for icing, wetting, and contaminating insulators. The slow melting and thawing of ice, which is produced by water deposited by fog, generates a highly conductive liquid film on the surface of insulators. Further study of these processes will allow the development



Annulus Gas Carbon-14 Removal System Using A Multi-Layer Calcium Hydroxide Absorber

of engineering or operational solutions to the problem.

The Chemical Department supports the Corporation's commitment to more efficient use of electricity and the byproducts of its production. To better utilize the inventory of heavy water, its potential non-nuclear use in the manufacture of deuterated materials is being investigated. This research has demonstrated that the substitution of deuterium for hydrogen can improve the oxidation resistance of many oils, greases, and polymers. Evaluation of several deuterated materials has shown that, with this substitution, the service lifetime of polymers can be increased by a factor of three and that of oils by over one hundred times. These improvements in performance can be obtained with any material that degrades by the oxidative breaking of carbon-hydrogen bonds, thus opening up many potential applications for heavy water use.

In support of the commitment to better utilize the byproducts of electricity production, research was undertaken to assess the feasibility of developing a commercially viable Malaysian prawn aquaculture scheme. This particular species of prawn was chosen because of its marketability, rapid growth rate, its large size, and its requirement for warm (27° to 30°C) water. Early stages of this research dealt with the improvement of food and space utilization. During the past year emphasis was placed on population characteristics to ensure uniformity of size.

In 1988, the results of the prawn research were applied in a small greenhouse demonstration with impressive results. The system that was tested yielded production rates equivalent to almost eight metric tons per hectare per year, which is about eight times the global average. In addition the prawns

developed to a marketable size in six months, half the commercial rate. The average prawn was 23 grams as compared with shrimp, which are typically harvested at 17 grams. Ninety-five percent of the animals were over 15 grams. Continuing research may improve on these results. Currently a financial study is being carried out, and if warranted, the feasibility of a pilot-scale plant will be considered.

Research aimed at more efficient use of electricity in the industrial sector is the subject of a project shared between Ontario Hydro and the University of Toronto. The aim of the project is to develop thin-film electrocatalysts that have high electrical conductivity and that exhibit electrocatalytic behaviour toward oxygen. The project uses special metal targets and sputtering. Sputtering is a process that allows small amounts of ionized gases to act as electrolytes for the transfer of metal ions in controlled environments. So far, a number of new materials have been fabricated, and characterization of their properties indicates that researchers are on the right track. Successful results could lead to inexpensive and highly efficient, oxygen-reducing electrodes with the potential to provide the electrochemical industry with large energy savings.

Concerns related to improving the reliability of Hydro's aging system components, plant life extension, and nuclear plant life assurance increased in 1988. Additionally, a greater awareness of environmental issues related to radioactive and hazardous waste management, climatic change, and electric and magnetic fields emerged. Many of the Department's activities are designed to address these issues. This indicates a challenging and interesting 1989 for the Chemical Research Department.

Transferring Technology an Important Activity

Since 1919, when the Civil Research Department was involved in developing the revolutionary water-to-cement ratio concept for mix proportioning of concrete, it has enjoyed an international reputation for excellence and innovation. Today this reputation is maintained in the course of meeting the stringent high standards of durability and performance required for the optimal and safe performance of Hydro's hydraulic, thermal, and nuclear stations.

The Department is considered to have one of the best-equipped cement and concrete laboratories in North America. In these laboratories, world class researchers are active in developing Canadian and international standards and in testing cement and concrete for the Canadian Standards Association (CSA), the American Society for Testing and Materials (ASTM), and the American Concrete Institute (ACI).

The laboratory is equipped to perform standard and specialized tests to determine interaction between cements, aggregates, admixtures, and external environmental conditions. The Department also has access to Divisional facilities in analytical chemistry, electron microscopy, and thermal and x-ray analysis.

Since 1920, all materials to be used in concrete destined for major construction projects have been subjected to pre-testing. Ontario Hydro is the only Canadian agency that independently analyzes the quality of cementing materials. Because of the large number of potentially unsuitable sources in all areas of Ontario and Ontario Hydro's empha-

sis on rehabilitation programs for older hydraulic structures, petrographic and physical testing of potential concrete aggregate sources has received renewed attention. Additionally, ACI-certified concrete inspectors provide on-site inspection and testing of concrete for conformance with project specifications and quality assurance. In 1988, for example, during the construction of the Darlington Nuclear Generating Station, approximately 75 000 cubic metres of concrete were inspected. Inspection and testing services were also provided by Civil Research personnel at Cedars Channel Dam and Crystal Falls GS.

For specialized applications, such as are necessary to assess the penetration of aggressive substances through concrete, research facilities are available for the measurement of permeability and pore size distribution. Additionally, studies were undertaken to develop concretes for specific applications in hostile environments produced by exposure to temperature extremes, acids or sulphates, and radioactive wastes. Concretes for special applications such as high density shielding, massive sections, and heavily reinforced structures were also developed.

A large, well-equipped concrete structural laboratory provides for proof testing of prototype structural components; a reaction-frame system permits an almost infinite variety of test configurations supported by servo-controlled load actuators and extensive instrumentation and data acquisition capabilities. The equipment has been used for projects as diverse as testing the effect of thermal gradients





on concrete used in nuclear stations and determining the effectiveness of shear keys in waterstops.

The Civil Research Department continues to provide consultation services and to review historical data for the Corporate Dam Safety Program. Additionally, the Department was involved in the assessment and refinement of nondestructive testing techniques for locating zones of anomalous behaviour. In situ testing techniques for assessing material properties were also pursued.

Nondestructive evaluation of the integrity of Ontario Hydro's older concrete structures is an important activity. In 1988, work was done in this area at Ear Falls GS, at DeCew Falls GS, as well as at transformer and major thermal stations. Methods of nondestructive testing included visual and microscopic inspection, ultrasonic testing, and electromagnetic location of steel reinforcement in concrete. The in situ strength of concrete was determined by the impact hammer, by Windsor probe, or by pullout tests.

Concurrent with investigations assessing the need for repair, new instrumentation was installed at R.H. Saunders GS. At this station, a void was detected at a depth of 58 metres, necessitating a new approach to the investigation of the foundation. An echo-sounding device was adapted for borehole operation and a strain gauge disc was adjusted for making measurements in the borehole. With the help of these devices and a TV camera capable of accessing the borehole, valuable investigative information, such as the shape and extent of the void as well as any surface features indicat-

ing possible dissolution of mineral intrusions in the rock, was obtained. The closed-circuit borehole camera was also used to investigate concrete conditions within the dams and rock conditions below the dams at Sandy Falls GS, Crystal Falls GS, and Ear Falls GS.

Dam safety assessment requires the testing of the shear strength of rock and concrete interfaces at dam foundations. At Stewartville GS and Hound Chute GS, values were obtained using direct shear equipment in the rock mechanics laboratory. An example of this technique is the use of the Soniscope to evaluate the integrity of concrete in hydraulic structures.

One innovative project of current interest is the development of a high-pressure water jetting device for cleaning plugged drains in concrete dams. Frequently drains get plugged with debris, which can lead to increased uplift pressure and potentially hazardous dam safety conditions. To counter these adverse effects, relief holes are drilled in the dam or water is applied under pressure to the drain from the crest of the dam. The concept under development in the Civil Research Department uses water jetting with concomitant high pressure (up to 35 000 psi), which is generated directly inside the drain rather than in the equipment servicing the water jetting device. Advantages of this method are greater efficiency, enhanced safety, and the ability to use higher pressure because high hydraulic pressures need not be transmitted over long distances.

Remote monitoring software developed in the Division



A universal testing machine is used to assess the shear capacity of a construction joint containing polyvinylchlorine (PVC) water stop, which is used in nuclear containment structures to prevent leakage.

continues to be used to monitor the stability of the rock cliff situated above Ontario Power GS, as well as to monitor the drain flow at Stewartville GS.

Participation in transmission line refurbishment studies included the evaluation of the condition and the load carrying capacity of foundations for transmission towers constructed more than 30 years ago. These studies provide a greater insight into the life expectancy and reliability of old lines. Probability-based calculation methods were adapted for design of transmission tower foundations.

Organic and inorganic materials, suitable for new construction and repair of structural elements of transmission tower foundations, are evaluated on a routine basis. For example, a very low-temperature polymer concrete was recently developed for use in severe weather conditions with temperatures as low as minus 25°C. Additionally, some specialized tests have been developed to meet Ontario Hydro's needs.

In the area of thermal plant waste management, the Civil Research Department continues to provide specialized geotechnical and hydrogeological research and consulting for the management of wastes and byproducts from Ontario Hydro's coal fired generating stations. Laboratory and field projects were conducted to investigate the movement of contaminants within the soil and rock strata beneath a coal ash lagoon at Nanticoke TGS. Innovative utilization options were assessed for dealing with the coal ash produced at Lakeview, Nanticoke, and Lambton TGSs. Typical approaches are the use of cement-stabilized fly ash as a potential fill material along a lake shoreline and the use of fly ash for soil amendment. Field investigations and monitoring were carried out to obtain useful data for the design of long-term fly ash mounds and for fly ash dust control. Several studies were completed with the objective of utilizing Flue Gas Desulphurization (FGD) byproducts, some of which may be produced at the coal fired stations in the

1990s. Evaluation of environmental consequences of contaminant migration and the development of waste disposal systems were the focus of much of our research in this area as to minimize possible environmental impact from waste materials.

Civil Research Department continued to support research and development efforts related to medium- and high-level radioactive waste disposal. Through Ontario Hydro's Technical Assistance Program (TAP), which supports the waste management program being carried out at AECL and Whiteshell Nuclear Research Establishment (WNRE), studies are ongoing in the near-field heat and moisture modelling experiment. The intention of these studies is to develop reference design for the underground disposal of irradiated fuel wastes. Additionally, studies are being carried out to investigate the hydraulic compression behaviour of shaft backfills. Ontario Hydro's technical expertise in thermal modelling was sought by AECL/WNRE for their Underground Research Laboratory (URL) experiments. These experiments are being carried out near Pinawa, Manitoba.

Although adequate methods exist for measuring the magnitude and orientation of strain, the design of underground excavations requires knowledge of in situ stress. Thus, the occurrence of high stresses in AECL's URL prompted the development, in the Civil Department, of a directional dilatometer for making in situ measurements of rock modulus. However, the rock modulus, which is a value needed for the calculation of stress, is measured in an isotropic manner rather than in relation to the in situ stress. This new instrument will enable a more exact calculation of the in situ stresses acting on an underground repository, which will in turn contribute to the increased safety of the excavation. In situ measurements obtained with this new instrument will be used to optimize the siting of the long-term storage facility Bruce NGS "B".



Cracks in chimney no. 2 of Lakeview TGS necessitate structural repair. Here, structural restoration is accomplished through the section of the concrete chimney, which is followed by epoxy injection.

Emphasizing R&D of Value to Ontario Industry

The Divisional Projects Department creates and maintains connections between various groups within the Division, within the Corporation, and with groups external to the Corporation. The Department's work falls into three broad categories, which are as follows: new technology initiatives, research management studies, and research business support.

In the area of new technology initiatives, the Department identifies areas of interest to groups within Hydro and to external organizations. A coordination and liaison function is then carried out to further the creation of joint research projects. To achieve this cooperation, advice and resources must be drawn from within the Research Division and the Corporation at large, as well as from industry and government.

In 1988, emphasis on the Division's participation in the development of electrotechnologies of value to Ontario industry continued. Examples include coordination of the plasma arc and advanced ceramics programs. In cooperation with the Metallurgical Research Department and the Marketing Branch, a research project in process metallurgy was established. An additional program involving the Ontario steel industry was initiated, and this project works toward the production of steel with concomitant reduced CO₂ emissions.

Another initiative, started last year, was in the area of industrial laser research. Out of this research grew the creation of the Canadian Industrial Laser Association. Connec-



tions with York University and the Laser and Lightwave Centre of Excellence are being maintained, and a proposal for the creation of a Network of Excellence in the area of high-powered lasers has been submitted.

To strengthen and broaden the Department's ability to create new initiatives, one of the Division's Senior Research Scientists was given a cross-appointment between Chemical and Divisional Projects Departments. The result was the development of an initiative to look at Ontario weather data from the past. Based on these data, potential climatic changes attributable to the "greenhouse" effect will be assessed.

The coordination of, and influence over, joint research activities has been increased by having members of the Department sit on either the Board of Directors or the Industrial Advisory Board of a number of organizations. The Ontario Centre for Materials Research (OCMR), the Ontario Laser and Lightwave Centre of Excellence, the Canadian University and Industry Council on Advanced Ceramics (CUICAC), and the Advanced Materials Technic Unit (AMTU) at Queen's University are some of these organizations. The scientific and engineering excellence of the involved staff members is maintained through Adjunct Professorships held at the University of Toronto and at York University.

In February of 1988, in the area of Research Management Studies, a paper on the Research Planning Process, which was developed within the Division, was presented at the



First International Conference on Technology Management.

The preparation of the 1988 Notable Accomplishment Report was started. This report is fashioned along the same lines as the one issued in 1984, which was very well received. Reports of this nature provide an important vehicle for a research organization such as this to demonstrate ongoing contributions of value to its parent organization.

To assist in the management of the Division's activities, a number of Standing Instructions were revised; one of these concerned the patenting of Research Division inventions.

In 1988, a new and more integrated approach was taken to the creation of the Division's 1989 to 1998 Business Plan. The approach involved the Divisional Projects Department in a coordinating role. The experience gained led not only to improvements in the plan but also in the process for its preparation.

The Artificial Intelligence (AI) Newsletter, which now has a new look, continues to serve as an up-to-date information device. The newsletter is of benefit to the AI community within Hydro as well as to the community outside, and the circulation of the Newsletter is increasing steadily. Neural networks continue to represent an important advance in AI technology. As part of a Divisional initiative, a neural network AI system has been acquired and will serve as a tool to investigate its applicability to a variety of pattern recognition problems faced by Hydro.

As part of the research business support work, the Department provides assistance to the rest of the Division in

the area of external contracts. This support includes the maintenance of Research Division information in a number of data bases, the upkeep of bidders lists, and liaison activities with contracting organizations. The Department also serves as a clearing house for external requests for proposals.

Again in 1988, the Department arranged over 30 tours of the Division. Visitors ranged from scientists and managers from utilities world-wide, through political dignitaries, to young high school and university students. Larger tours have also been arranged for members of scientific and technical societies. These activities are most positive in that they raise the profile of both Hydro and the Division in the eyes of the public.

The 1987 Research Division Annual Report, which contained a historical review of the Division's activities over its first 75 years of existence, is a typical example of the fine reports and brochures produced by the Department.

A number of technical information sheets, such as are typified by the REDIFAX, were produced with the help of Divisional Services Department. A new fact card targeted at visitors to the Division, Pocket Facts, was also introduced in 1988. The card is so designed as to allow it to double as a name tag.

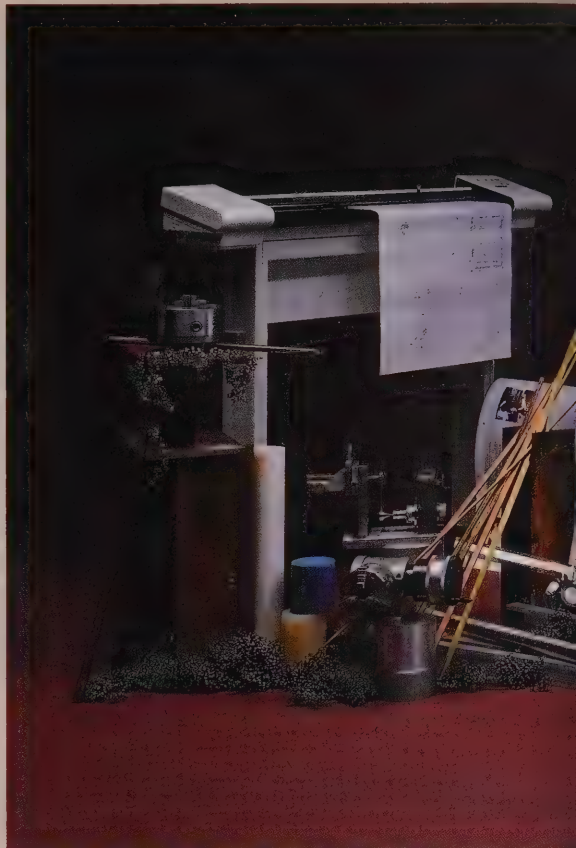
Supporting the Needs of the Research Division

The function of the Divisional Services Department is to offer support to Ontario Hydro's Research Division. It provides services including report production; business administration; financial reporting; records, space, and safety management; printing and clerical services; model shop production; drafting; photography; payroll; and editorial services. During 1988, the Department continued to expand and upgrade its services in order to supply more efficient and innovative assistance to meet the varied needs of the Research Division.

In the Business Administration Section, the Records Management Program is proceeding smoothly. All Section and Department files in the Mechanical Research Department have been converted to a standard Corporate General Subject Index and modified, when practical, to satisfy user needs. The Chemical Research Department's administrative files had all been converted to the Index by the end of 1988. Thus far, the revised file numbering system has gained popular acceptance by users. Some additional results of the new system and procedures include a reduction in filing space through the elimination of duplicate copies and older files, as well as improved access to more current files.

Recently, a medium-volume photocopier was added to the Photocopy Centre. The new machine provides a backup resource comparable to the already available high-volume copier. Both machines ensure a high-quality copy for internally produced Research reports.

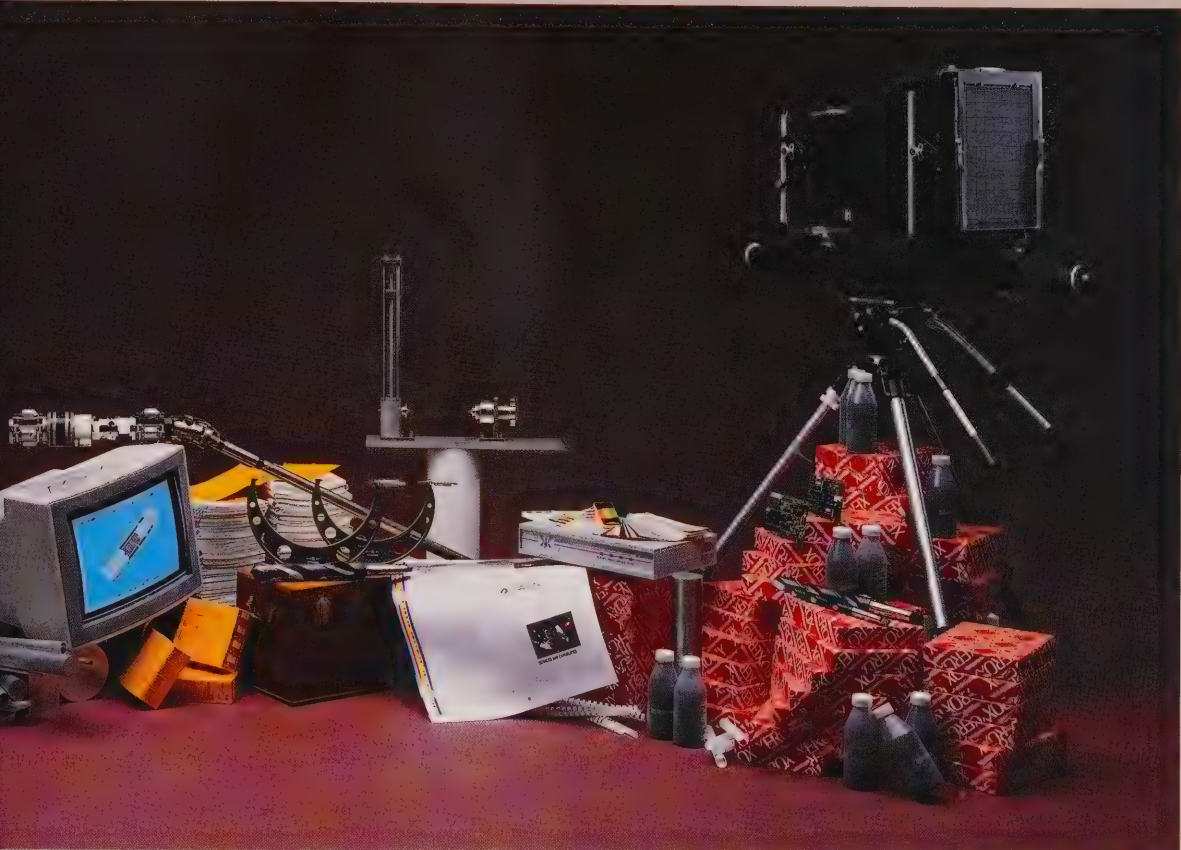
This year saw the introduction of broadcast video to the



Division. Video presentations have travelled to China in aid of CIDA-EPCRI, whereas more locally they have informed employees with a series on retirement planning. The productions are ongoing; in the latter part of 1988, a video production was completed that not only describes how the Division functions, but also provides a historical overview of the Division's growth and development. The video production is of particular interest in that it includes considerable original historical footage discovered only accidentally by Divisional Services personnel engaged in researching the production. This video production will be used in the orientation of new employees and in the promotion of the Division's work internationally.

One event of particular interest concerned the Photographic Services Section's involvement in recent cask-coupler impact tests. When asked by the Nuclear Materials Unit to aid in recording data during a major nuclear cask qualification test, the section responded by developing remote-controlled photographic techniques for use in hazardous environments. Cameras wired to a custom-designed remote-control board allowed film to be shot in high-speed 16-mm, 35-mm, and motion picture formats. All three formats were successful.

The Research Publications Office has had a busy year. In addition to putting out a special anniversary edition of the Research Annual, the office was involved in developing and publishing promotional material for the Division. Office staff did much of the background research necessary for the



orientation video and were responsible for the writing of the round track.

The most recent publication to come out of the Research Publications Office is the first in a series of bookmarks designed to inform personnel of the services offered to the Research Division by the Divisional Services Department. The reverse side of each bookmark gives an anecdotal account of the contributions made to the Division by a significant Hydro figure. Other series are planned. Besides working on promotional material, the Research Publications Office provided editorial support during the compilation of the Division's Annual Business Plan and the Annual Budget. The Office looks forward to reviving the currently dormant "Research Review" as soon as possible. All aspects of the efforts of the Research Publications Office are expected to be enhanced in 1989 by the recent acquisition of a sophisticated desktop publishing system.

The Drafting Office's improvements, begun in 1987, are continuing. A major innovation is the extensive use made of the Super Mac II and AutoCad systems, both of which facilitate all aspects of drafting, design, and illustration. Revisions can be done quickly, the line work and text always being clear and consistent.

In addition to its customary duties, the Drafting Office is providing designs to improve the decor and the work environment of the Division. With the aid of Building Services, a mural was executed for the Nondestructive Fracture Evaluation (NDFE) Section. The design was tailored to the needs of

the laboratory personnel. Other projects are being planned and will provide additional working areas with a "face-lift". Colour schemes are being coordinated with office furniture, and photographs and mural paintings will be incorporated to reflect the work histories of particular sections.

The Model Shop has significantly upgraded its support capabilities. This has been achieved through the acquisition of new equipment, tooling, and increased interaction and feedback between customers and staff. With higher accuracy as a goal in the upgrading process, machines have been replaced, numerical control equipment has been introduced, and all machine tool axes have been equipped with linear encoders.

Within the Research Division, the facility has met many requests for the machining and development needs related to zirconium metallurgy; tritium technology; mechanical testing; applied mechanics; inspection instrumentation; material transport; and electrical, transmission, microwave, bioelectromagnetic, chemical, biological, environmental, physical science, and civil studies. Examples of these activities include the fabrication of a pressure tube burst-test facility, an ultrasonic inspection tank, x-ray-induced partial discharge apparatus, rat cage enclosures developed for the Biological Effects of Electro-Magnetic Fields (BEEF) study, microwave guides, rotators for fuel bundle inspection, ring gaps, fatigue test apparatus, fuel channel resistivity probes, and carbon-14 monitors.

Emphasizing More Efficient Use of Electricity

Research and development activities in the Electrical Research Department are mainly focused on providing support for the bulk power system and the municipal distribution systems. The Department, which has a staff complement of 86 professionals and 67 technical and administrative support staff, is also engaged in comprehensive studies of new techniques of benefit to the Corporation and its customers in both the near- and long-term. What follows is an overview of some departmental activities of major interest.

In 1988, in consideration of the financial and environmental constraints imposed on the Corporation, a major share of the Electrical Research Department's resources was directed toward maintaining a secure power system. As part of this effort, stability control continued to play an important role for Ontario Hydro's power system, which is limited by its transmission capabilities. New power system stabilizers were installed for hydraulic generators and for the enhancement of the control systems of nuclear and fossil-fired units, thereby allowing a greater contribution to the damping of all modes of system oscillation. Further benefits are also expected from the development and validation of better theoretical models of large power system components.

Because Hydro's power system is being operated so close to its limit, it is imperative that any disturbances that do occur be analyzed and understood. To this end, a power system disturbance recorder has been developed that can record voltage and power swings during such disturbances. Data obtained with this recorder are being collected for sub-

sequent analysis. Once stored in a computer-based system the data can be accessed remotely over telephone lines and then analyzed with a view to implementing measures to improve system performance.

To address increasing concerns expressed by the individual as well as by commercial and residential customers, modelling studies were extended to assess the effect of arc-furnaces on voltage flicker. A new modelling study, developed for the CEA, will provide an essential tool when proposals for arc-furnace installations are being evaluated.

Recognizing the need to predict and understand the performance of complex power systems, the Electrical Research Department continues its participation in an international project aimed at the development of comprehensive models of the transient performance of large power systems. Currently underway is a cooperative effort to develop and validate a transformer model.

Another analytical study, one with potentially far-reaching consequences, involves the evaluation of economic benefits that can be derived from a new low-loss transmission line conductor. The evaluation shows that, if, in the coming decades, these conductors were to be universally adopted in Canada, the reduction in transmission losses could result in significant dollar savings and deferment of several hundred megawatts of generation. Additional adoption of these new, compact conductors would not result in additional costs to the Corporation.

The CEA and the EPRI continue to contribute significant





unding to Hydro's electrical R & D program. In addition, other organizations — which include the Canadian Fusion Fuels Technology Program, COG, the Municipal Electrical Association, and some American utilities — provide funding to specific research projects of benefit to both the funding organization and Ontario Hydro. Whereas most of these externally supported studies addressed near-term problems, longer-term concerns are receiving increasing attention.

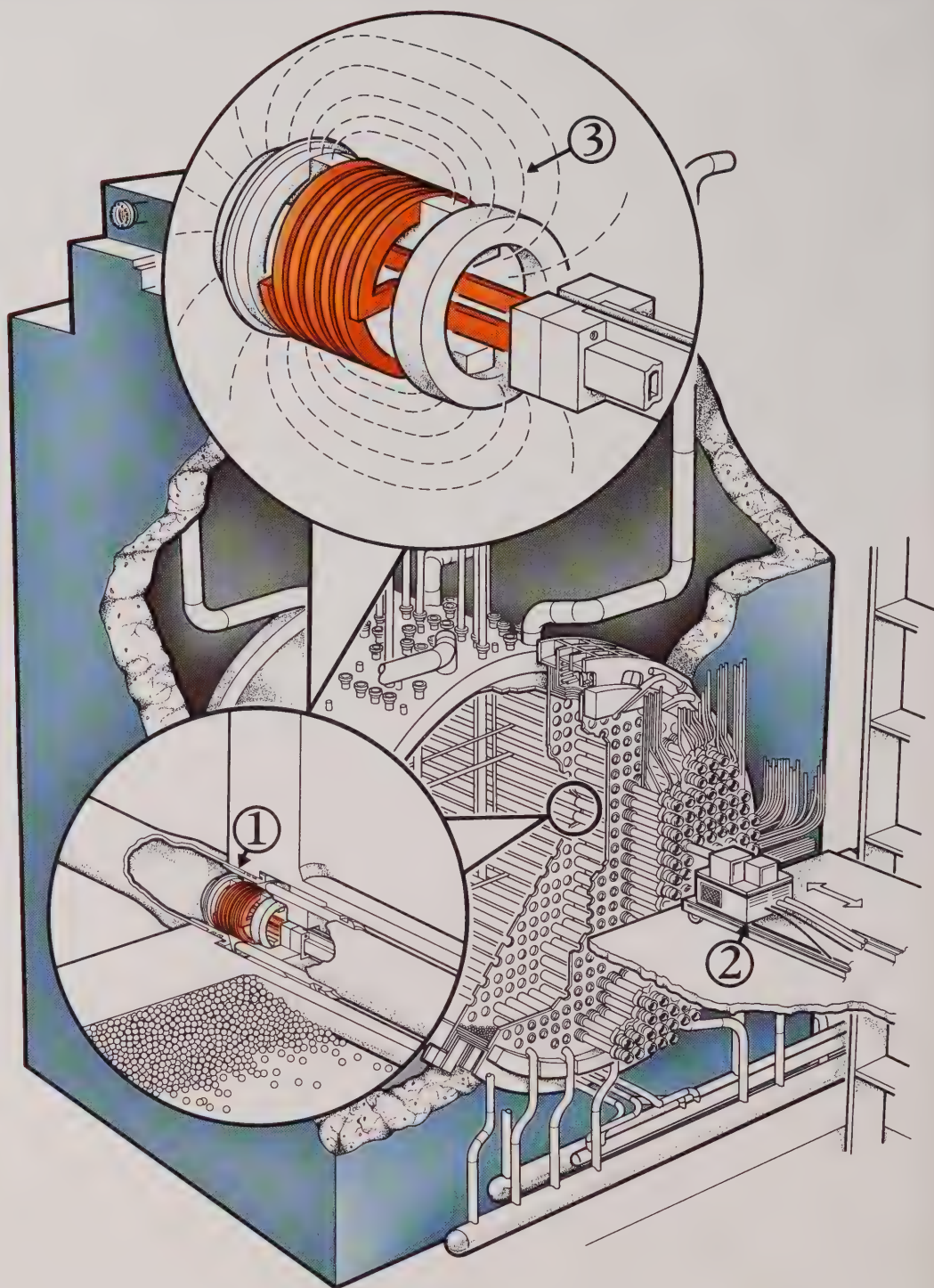
One area of theoretical research, the introduction of artificial intelligence to power system operation and maintenance, shows great promise. In addition to the Generator Expert Monitoring System (GEMS) now being developed for EPRI, other useful explorations focus on intelligent mobile robots with applications for maintenance in hazardous locations. This latter project is collaborative, involving AECL, the University of Toronto, and York University. Most of the funding will come from Precompetitive Applied Research Network (PRECARN) Associates, a non-profit consortium of Canadian industrial companies.

Whereas better analytical techniques are becoming increasingly important in deriving maximum benefit from new technologies, much attention is focused on the performance and improvement of power system components. Currently, the Electrical Research Department is participating in a multidisciplinary research program with the Chemical Research Department, the Metallurgical Research Department, AECL CANDU Operations, and AECL Research Company to assess a new technology with the ability to detect and

locate minute leaks in reactor pressure tube systems. The project, which is funded by COG, is currently involved with assessing the ability of state-of-the-art diode lasers to detect heavy water via absorption spectroscopy.

Of continuing interest is the behaviour of high-voltage insulators under severe weather conditions. Studies on insulator behaviour began in 1986 as a response to serious concerns about the reliability of the power system under specific weather conditions. At that time, the performance of high-voltage insulators used in transformer stations and on 500-kV transmission lines was studied both during and after ice storms. Now, in cooperation with the Power System Operations Division, the program has been expanded, and stations and transmission insulators are tested in a wider range of simulated weather patterns. The objective of this broader study is to establish well-supported performance characteristics that can then be used in the making of operational decisions about "safe posture" procedures needed to ensure secure power delivery under adverse conditions.

To ensure experimental repeatability and to permit accurate formulation of new test standards, much attention was given this year to making improvements in the design and operation of the Division's High-Voltage Laboratory's test chamber. Now the chamber can accommodate careful control of temperature, humidity, precipitation rate, droplet size, wind speed, and wind direction. This upgraded laboratory, with these highly specialized climate controls, is now in continuous use and will likely become essential for establish-



The process of removing a calandria tube in a CANDU reactor is as follows: The rolled joint (1), which holds the calandria tube firmly in place, is rapidly heated but cannot expand in the cold surrounding tubesheet. After cooling, the calandria tube shrinks and can be readily removed. The carefully controlled "shock heating" process is performed with a mobile high-frequency power supply (2) and a water-cooled induction coil (3).



A 500-kV load break interrupter is undergoing a bias voltage test.

ing new insulator test specifications and for developing new insulation designs to meet winter performance specifications. The absence of a meaningful winter performance specification for high-voltage insulators at present can be attributed to the lack of adequate testing facilities.

Whereas outdoor insulation reliability is mostly a concern of northern climates, the performance of enclosed high-voltage insulation systems is receiving increasing attention among all major utilities. During the past two decades, many promising, but untried insulation techniques have been introduced in power equipment and underground cables. In general, manufacturers, as well as utilities, have moved cautiously; in final analysis, however, only operating experience itself can establish the success of new technology. This is particularly true for highly stressed compressed-gas insulation systems that are used in switchgear at voltages of 230 kV and above. To reduce the risk of unexpected operating problems as much as possible, Ontario Hydro has maintained an ongoing research program to assess the performance of SF₆-gas-insulated switchgear and bus ducts during the past 15 years.

Several recent investigations, which were carried out under contract to either CEA or EPRI, resulted in better specifications for acceptance testing of new equipment and for identifying potential failure mechanisms. A current research project on the reliability and life expectancy of spacer insulators in compressed-gas bus ducts is aimed at identifying and analyzing aging mechanisms in the filled polymers used in these insulators. This study, which is co-funded by EPRI, will provide the basis for the development of ultra-sensitive diagnostic techniques for the early detection of insulation weaknesses.

Following the development of an on-line technique to monitor degradation processes in the insulation of hydraulic generators, attention became focused on thermal generators not readily able to accommodate recently developed and necessary instrumentation. This new initiative, supported by CEA, addressed several serious technical difficulties. Promising results are being obtained. The feasibility of

instrumentation for monitoring generators at nuclear and fossil-fired plants has been demonstrated, and this is expected to become available in the near future.

Electromagnetic phenomena of benefit to Ontario Hydro's Corporate Nuclear Program and Industrial Marketing Department, as well as to industry at large, are studied and harnessed in the Electromagnetic Laboratory. Some applications produced by these efforts well suit the repair and assembly of nuclear reactors. The resulting savings to the Corporation are substantial.

The induction coil, illustrated in this overview of the Electrical Department's activities, was developed in this laboratory. The rapid induction heating process allows the separation of calandria tube and pressure tube rolled joints in CANDU reactors. The process reduces the tube diameter, which makes possible the removal of tubes without significant mechanical force. Future research will focus on the development of remotely operated equipment for use in the rehabilitation, repair, and decommissioning of nuclear facilities.

Power system protection continues to be an area of major interest. The increased use of Application Specific Integrated Circuits (ASICs) in equipment being developed for application in protective systems is providing functional as well as economic benefits. In one case, the circuitry required for three different projects was combined into one ASIC, thereby resulting in a significant cost saving. Additionally, an ASIC was designed to upgrade the performance of the widely used (about 1 000 units installed per year) HTDX timing relay. This one relay now provides digitally controlled time delays of up to 40 minutes and adapts automatically to battery voltages from 40 to 280 V. The evaluation of protective relay systems for series-compensated lines moved into high gear with the development of both hardware and software to support the testing program. Several evaluations of new relays and systems were carried out for the Corporation as well as for other utilities. A new stator ground relay, developed in 1986, was installed on all units at the Lakeview Generating Station. In cooperation with several



Exposure systems for Ontario Hydro's Magnetic Field Rodent Reproductive Study (MFRRS) were supplied by Research Division. This experiment, which was designed to address the concerns of video display unit operators, is currently being performed at the University of Toronto.

Divisions in Ontario Hydro, a program to conduct research in digital communications has been initiated; this option is becoming increasingly attractive for supporting reliable protection and control systems. In concert with this development, work on novel protection schemes that take advantage of high-speed digital communications has been reactivated.

The compatibility of power lines with communications facilities continues to be important. Preconstruction electromagnetic interference surveys were completed on routes for new 500-kV lines as were investigations related to broadcast signal re-radiation. Another area of concern is the possible interaction between power-line carrier and navigation facilities. This is the subject of an ongoing study carried out for CEA.

Several distribution system studies were undertaken as part of a program to increase technical support for municipal utilities in Ontario. Of particular interest is a CEA-funded project that addresses issues concerning transformer security and reliability. This particular study, initiated in response to concerns about equipment failures that could be violent, analyzed the ability of oil-immersed current-limiting fuses in transformers to withstand electrical and mechanical impulses. The outcome was the development of carefully controlled test procedures to be included in standard specifications to ensure that new fuse products can safely withstand normal field occurrences. It is interesting to note that the experience gained in this study also yielded recommendations for improvements in fuse design. Recognizing that 90 percent of customer interruptions can be traced to failures in the distribution system, Ontario Hydro and the CEA initiated a joint project to examine the effects of lightning on the reliability of distribution networks. The study involves the correlation of lightning activity with system outages, which allows identification of those components and system configurations most susceptible to failure during lightning storms.

Following the issue of a CSA standard on gapless metal-oxide surge arresters for alternating current systems, a comprehensive application guide for distribution surge arresters was completed under contract to the CEA. This guide, which recognizes different design philosophies, is the first of its kind in the industry and is intended to help distribution utilities in designing surge protection for systems operating at 2.4 to 50 kV.

With the upsurge of interest in time-of-use rates as a load management incentive, a need to assess the suitability of metering equipment available for this new rate structure in the commercial and residential market became apparent. The assessment revealed that, although little is currently available with the necessary Canadian approvals, manufacturers are responding to Ontario Hydro's expressed interest. It is expected that new Canadian approved metering systems will soon appear.

The efficient use of electricity can produce benefits for Hydro's customers and for the power system. Both residential and commercial customers can lower their heating bills by using either bivalent (propane/electric) or ground-coupled heat pumps while reducing demands on the power system by 50 percent when compared with standard electric heating. This year the performance and reliability of these systems have increased.

In 1988, water heating systems also received attention. Demonstrations of efficient systems continued for commer-



Technicians are in the process of erecting a 700-kV resonant test set for calibration before testing gas-insulated stations.

cial applications that reduce power demands by at least 40 percent while they improve working conditions in restaurant kitchens and laundries. A unique water heating manual, which covers the theory, equipment, methods of sizing, installation, and maintenance of water heating systems, was prepared for the CEA. This manual has received world-wide attention and is becoming an indispensable tool for utilities, designers, and users.

The Department continues to assist industrial customers determine the benefits of using dehumidification, microwave, infrared, lasers, and various other electrotechnologies in their production facilities, the objective being to reduce energy costs, to improve productivity, and to enhance competitiveness. Working with energy management personnel from both the Regional and Head Office, the Electrical Department was able to provide over 60 industrial customers with complete technical and financial evaluation packages. These packages were based on the results of both laboratory and analytical work. A study done by Central Region showed a high implementation rate of these electrotechnologies by industry with 20 percent of the research projects implemented and another 30 percent currently under active consideration. Overall, the Electrical Department's collaborative and individual efforts to effect the more efficient use of electrotechnologies, for the benefit of the customer and the Corporation, yielded successful and promising results throughout 1988.

Supporting Safety and Reliability

The Mechanical Research Department's work activities through 1988 provided strong support to the Nuclear and Transmission System Program areas. Support activities involved provision of testing services and technical investigations, problem solving, and research studies performed in support of safety and reliability issues.

To verify safe and reliable behaviour of equipment, structures, and components, both modelling and full-scale tests were used. In the environmental qualification field, one highlight was a steam-environment qualification test of a heat-transport pump circuit breaker. These breakers are required to trip pumps off line under various postulated accident conditions. One such condition occurs when a main steam-line breaks. Under these circumstances the circuit breaker and its control cabinet become enveloped in low-pressure steam. Direct testing in the laboratory demonstrated that the breaker could successfully trip the pumpset. Many smaller components that perform electrical, instrumentation, and control functions were also tested during the course of the year, thereby contributing to the analysis and engineering of nuclear plant safety.

The Department's Applied Mechanics Section is currently involved in the development of safe methods of storage, transportation, and ultimate disposal of high- and low-level nuclear wastes. Under development are a tritiated heavy water transportation package, an irradiated fuel transportation cask, a concrete integrated container for transportation and storage of used fuel, and iron based stressed shell (IBSS)



and thin walled particulate packed (TWPP) containers to be used for the ultimate disposal of irradiated fuel. Nine-metre drop tests and extensive finite element analyses have demonstrated the impact resistance of the tritiated heavy water transportation package, and on the strength of this work, a transportation license has been obtained from the Atomic Energy Control Board (AECB). Tests of impact and of fire resistance under accident conditions have demonstrated the integrity of the container intended to transport irradiated fuel. Additionally, an extensive program related to the concrete integrated container is underway. The work program includes finite element analysis, drop tests, and fire tests. The development and testing work related to TWPP and IBSS containers for the ultimate disposal of irradiated fuel is progressing well. The Section staff have provided a lead role in coordinating Research Division's efforts related to the containment and immobilization of irradiated fuel.

The Corporate Business Plan for 1988-1997 identifies deterioration in the reliability of Ontario Hydro's transmission system as being of major concern. This deterioration, which has occurred over the last few years, is due to the lack of sufficient resources for maintenance aggravated by the effects of aging. Almost one-third of the total circuit kilometres of Hydro's transmission lines are more than 40 years old. It is estimated that the incremental cost to customers in 1987 due to this deterioration was in the order of 10 to 15 million dollars. As a result, major replacement and refurbishment programs must be undertaken.



In 1988, to begin the refurbishment process, a program with a budget of \$1.75 million was approved and carried out. The program, which involved Design and Construction Branch and several Departments of the Research Division, comprised a cooperative effort to assess the condition and residual strength of 115-kV Kingston towers, line hardware, conductors, insulators, and foundations on a line south of Smith Falls. A short section of the line, which was built in 1929, was in the process of being rerouted. Three towers that were scheduled to be replaced were tested to destruction in the field. Also, a number of grillages and rock anchors were completed, along with laboratory tests on the insulators, conductors, and line hardware. The results of these tests indicate that this line is in good condition. Further tests on other lines are scheduled for 1989.

Other activities in the transmission system area included the evaluation of fibre optic overhead groundwires. Cables from various manufacturers were evaluated to determine their fatigue strength and performance under galloping and aeolian vibration loads.

Studies related to the control of vibration of overhead lines are continuing. Independent statistical analysis revealed that the average amplitude attributable to ice on four-conductor bundle lines can be reduced 17 percent by addition of detuning pendulums. Dampers for aeolian vibration control and spacer dampers to control wake-induced and aeolian vibration of bundle conductors are undergoing comparative damping measurements to assure

reliable protection against conductor fatigue in the field. A CEA-sponsored program to determine the wind energy transferred to bundle conductors with various configurations was completed in cooperation with the University of Toronto. The project demonstrated the possibility of alternative bundle conductor arrangements that would suffer less vibration and fatigue than do present designs.

An important facet of the Mechanical Department's work program concerned the technical investigation and resolution of problem solving issues related to efforts to improve plant equipment reliability and reduce operating costs. Contributions to the resolution of several major vibration-related problems affecting piping systems at the Pickering and Darlington NGSs were made. New and revolutionary methods, such as one that analyses the direction of vibrational energy flow in piping, were used to identify the sources of vibration. The method, which was developed in the Fluid Dynamics Laboratory, contributed to design modifications that solved the problem.

A number of problems related to rotating equipment and structural vibration in generating plants were corrected. Methods based on experimental and theoretical rotor and structural dynamic analysis were used to identify the causes and to determine effective and economical solutions.

The introduction of new, and the expansion of existing, computer-based condition monitoring systems in a number of generating plants is progressing. These systems provide maintenance personnel with useful information about main-



Greg Morandin, a technologist in the Applied Mechanics Section, is collecting data that will be used in the development of transportation containers for irradiated fuel.

tenance requirements. The result is greater equipment reliability at less cost, since required maintenance is done in a timely manner, and any unnecessary maintenance is eliminated. Research is in progress to improve the diagnostic capability of these systems by the use of advanced signature analysis techniques, expert systems, and neural networks.

Consultative and technical services were provided to groups both internal and external to the Corporation. Noise assessments and controls for power transformers, reactors, and cooling fans at transformer and distribution stations were some areas of recent concern. Improvements were made to equipment and methodologies, and these now enable the surveying and predicting of noise levels in the vicinity of transformer stations. Noise levels vary because of different configurations of layout and acoustical treatment of the walls of the enclosure.

An ongoing study on audible noise emanating from the single circuit transmission line (corona noise) was expanded to include a double-circuit 500-kV line at a site near Milton. A technique was developed for automatically monitoring and collecting information from occurrences of corona noise. The technique is capable of differentiating corona noises from other sources of noise such as are produced by weather conditions. The technique is proving to be reliable over a wide range of meteorological and background noise conditions.

Some of the Department's research and development activities feature work on aerosols and aerosol transport. Further data were collected for the Steam-Water Iodine-Partitioning Experiment (SWIPE). The objective of the experiment is to determine how radioactive iodine "partitions" between liquid and vapour phases in a flashing water jet. Also addressed, both theoretically and experimentally, was the physical transport of aerosol particles by flow within containment. These studies are important because partitioning and transport are key links toward improving estimates of potential radioactive leakage under accident conditions.

Another research project seeks to develop methods for monitoring the condition of primary heat transport (PHT) pump sets by means of vibration analysis.

Study continues on the finite element analysis of hydride blister formation in CANDU reactor pressure tubes. Two- and three-dimensional mathematical models are being developed to predict hydrogen transport and blister growth and to indicate the useful life of pressure tubes under a variety of service conditions. Another project related to pressure tubes is one in which modifications are being made to Creep Degradation Evaluation in Pressure Tubes, Hydrogen (CDEPTH), a computer program for predicting pressure tube creep and elongation. The modifications will allow direct comparison of analytically predicted results with in-reactor measurements. The Department has also been active in the large-scale fuel-channel replacement program at Pickering NGS and in rehabilitation programs such as the West Shift Operation at Bruce. Construction of the Burst Test Facility for doing pressure tests on large vessels, pressure tubes, and piping components is now complete. The commissioning tests on the facility are expected to be complete by the end of 1988. The facility will also be used for the "leak-before-break" work program related to the Darlington PHT piping system.

The demand for the Department's services to solve nuclear plant component integrity problems continued to be high in 1988. Examples included those related to the Bruce Nuclear Generating Station's de-aerator vessel, Darlington feeder pipes, Pickering's spacer rods, and other general steam generator problems. The staff also played a lead role in a number of multidisciplinary programs that arose as part of the Nuclear Plant Life Assurance Program, the acquisition of naturally aged material and component samples from the decommissioning of the NPD, and the investigation of the long-term effects of the load-following operation on the reliability of nuclear plant equipment.



A seventh-scale model of Ontario Hydro's Irradiated Fuel Transportation Cask (yellow and green) collides with a model locomotive (gray). To achieve a 65-mph collision, the cask model was accelerated with a rocket motor as it fell.

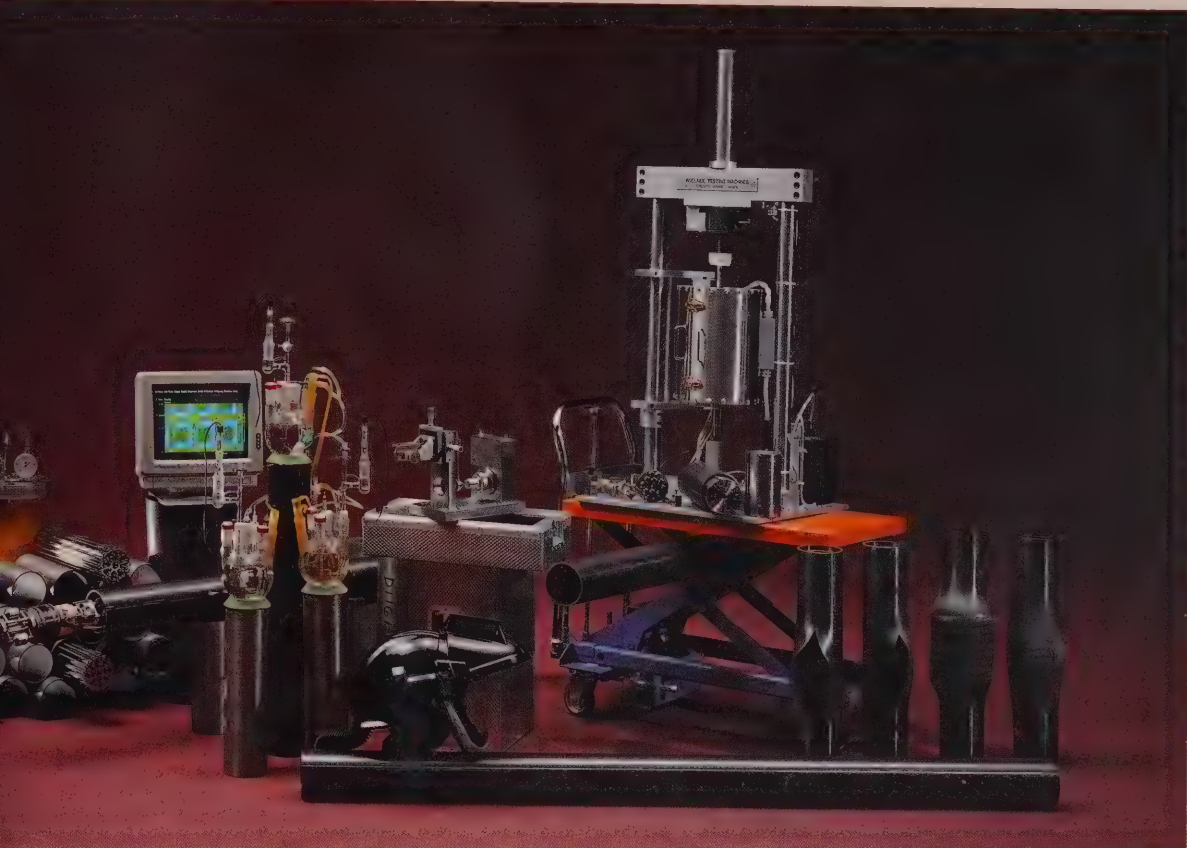
Helping Maintain Optimal Generation Capacity

The metallurgical discipline comprises many diverse technologies, ranging in scope from metal physics to extractive metallurgy. The work of the Metallurgical Research Department, therefore, covers a number of disparate technical areas. For example, fracture mechanics and nondestructive evaluation are two very different technologies, yet, in context of this discipline, they are complementary. In fracture mechanics, metallurgists seek to predict the performance of materials, components, and structures through both analysis and experiment; in nondestructive evaluation they attempt to discover imperfections that may lead to a structure's early demise. The two technologies meld, however, when considering the impact of a defect: nondestructive evaluation is the means through which the defect is discovered and described in spatial terms, and fracture mechanics is the route through which this information is used to determine the repercussions of the defect's presence. Neither technology, however, is limited to the narrow bounds of defect-structure interaction.

The prime thrust of the Department's work program is in support of CANDU technology. The work is balanced in terms of forward looking research (long-term); shorter-term research, primarily funded by COG; and technology transfer to groups such as Central Nuclear Services (CNS) and Design and Development—Generation Division. The work is divided among four sections, namely Materials Integrity, Corrosion & Tritium Technology, Metallurgy, and Nondestructive and Fracture Evaluation.



The Materials Integrity Section utilizes analytical and test techniques designed to investigate factors controlling the deformation (irradiation-enhanced creep and growth) and fracture (delayed hydride cracking) aspects of core components in CANDU reactors, particularly the zirconium-niobium pressure tubes. An important part of these studies is to achieve end-of-life conditions in the specimens in advance of actual in-service components. With respect to irradiation, this is achieved by testing in high-neutron flux reactors, which are available in the United Kingdom and France. Data resulting from these tests will provide input useful in the development of design equations and additionally will establish which microstructures in pressure tubes could result in a reduced in-service deformation rate. In fracture-related studies, concentrations of hydrogen are increased to suspected end-of-life levels. Crack nucleation and growth are studied, and the influence of both metallurgical and operating parameters on these processes is evaluated. A specific nucleation mechanism, currently the focus of significant attention, concerns the formation of hydride blisters on the outside surface of the pressure tube. Detailed studies of the growth of these blisters have been performed, and tests to determine the size of blister able to nucleate a crack have been carried out. The objectives of these fracture and deformation studies are to develop predictive capabilities such that reactor maintenance can be properly planned; to ensure that no unwelcome surprises occur during in-service performance of pressure tubes; and to identify how the microstruc-



ture of pressure tubes could be modified to give improved in-service performance.

An important initiative of the Corrosion and Tritium Technology Section is focused on establishing a detailed understanding of the principal source and ingress routes of deuterium into the zirconium alloy pressure tubes. Eventual control of hydrogen levels, to keep them below those levels that will cause fracture problems, is the expected result of this research. It has been established that corrosion of the alloy by the heavy water coolant is one ingress route. A normally protective barrier of oxide film keeps deuterium ingress rates low, but when the film's protective qualities are damaged or lost, accelerated ingress may result. Laboratory tests to establish the precise role of temperature, oxide features, and surface properties on the corrosion process are in progress. Extremely high-resolution state-of-the-art imaging, surface analysis, and electrochemical methods are being used.

Other possible ingress processes are being evaluated, and these involve interaction with the gas annulus environment and study of the microstructural changes in bulk alloy that occur as a response to in-reactor aging. Additionally the correlation of reaction kinetics and reaction products with deuterium absorption is being explored under simulated reactor conditions.

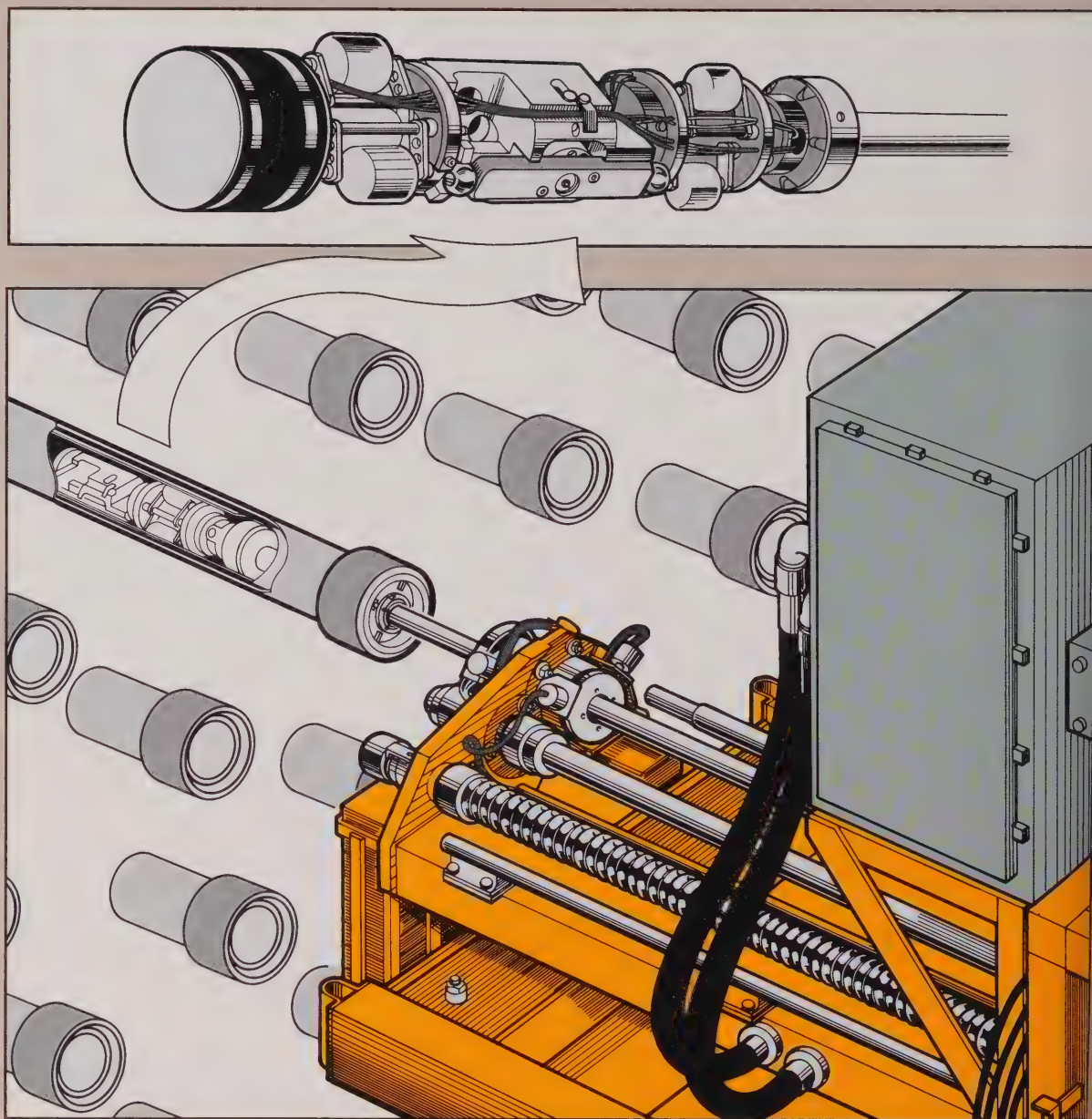
Fracture mechanics technology is extensively applied in support of the Corporation's nuclear generation program. A pressure tube burst-test facility has been commissioned and

is being used to study the fracture of pressure tube sections exhibiting surface cracks. Tests performed in the facility will supplement small-specimen tests currently being performed to investigate the effects of hydride structure on tube fracture toughness. A high-pressure and high-temperature autoclave is being commissioned and will be used to fatigue-test zirconium-niobium specimens in an operating environment.

The Nondestructive Evaluation Unit's principal involvement is also with fuel channels. The complexity of current nondestructive evaluation technology demands an integrated multidisciplinary team approach. Thus, in addition to involvement in the primary technologies of acoustic emission, eddy current, ultrasonics, and spatial measurements, the team relies heavily on computer technology, signal processing, and electromechanical design.

This cooperative arrangement has proven very beneficial in highly automated projects, such as in the recently developed award-winning CIGAR. Pushed by remote control down the fuel channel by a large, external, electromechanical machine, the apparatus goes to the core of CANDU's nuclear reactors to find cracks, to measure the diameter and thickness of pressure tubes, and to detect changes brought about by heat and radiation. To achieve this end, computers, electromechanical components, lasers and laser beam image recorders, optics and optical tooling, and machine tool control systems were utilized.

Eddy current technology was also utilized in pressure tube work. The focus was on the development of deconvolu-



Shown here is a profilometry module, a device designed to monitor wear in pressure tubes by producing profiles of wear/erosion and debris damage in fuel channels. The device, developed by the Nondestructive Evaluation Unit, is used in conjunction with the CIGAR system.

tion techniques to improve the quality of information provided by inspection systems. Additional interest centred on the design and prototyping of a resistivity measuring system that will be used to determine hydrogen concentrations in pressure tubes.

Ultrasonic technology is being utilized to detect, charac-

terize, locate, and size flaws in pressure tubes through processes such as crack-tip diffraction and "B-scans". Additionally, very high-frequency ultrasonics have been applied successfully to imaging lap-like defects. It was such a defect that caused the failure of a pressure tube at Bruce NGS. Ultrasonic techniques may also be useful in a process cur-

rently being investigated to measure hydride platelet concentrations in pressure tubes.

Although the Department has a heavy commitment to the fuel channel research program, other components of nuclear generating plant must receive attention. In pressurized water reactors, steam generator tubing is susceptible to stress corrosion cracking, localized corrosion under sludge deposits, and corrosion fatigue. To predict the susceptibility of the CANDU system to these mechanisms, exposure testing using laboratory simulations is being carried out. The result will be the establishment of a data base applicable to CANDU operating variables. Temperature, alloy heat treatment, and water chemistry are considered key factors in these corrosion mechanisms.

To study localized corrosion initiation and propagation effects in Lake Ontario water, heat exchanger test rigs continue to operate at the Pickering and Darlington nuclear stations. Testing to date suggests the probable central role played by microbiological action. The rigs facilitate the realistic testing of remedial measures such as chemical cleaning and biociding. A technique of measuring the corrosion rate electrochemically is being developed.

Effort on the Darlington Heat Transport System Leak-Before-Break study focused largely on providing analytical support to the Design and Development Division regarding the three-dimensional elastic-plastic fracture mechanic analysis of elbows and T-junctions and on producing documents for the Darlington licensing submissions.

The Department's work done in support of thermal plant was concentrated in the life extension program. Sections of large components taken from Lakeview TGS were sent to the Research Division for examination. These samples will provide a rare opportunity to investigate the age-related degradation of carbon steel pipes, components, and welds that have been in service for almost 20 years. Testing of the samples will begin in 1989, the purpose being to evaluate the suitability of these materials for plant use well beyond their initial design life of 30 years. The largest single project being carried out in support of thermal plant is the metallurgical "fingerprinting program", which is part of the Lambton life assessment program. Because this is described in the earlier article on the Division's contributions to Corporate Strategy, it requires little mention here except to note that the *in situ* metallurgical evaluation capability is subject to continual development and that the capability is frequently called upon.

Other work related to thermal plant metallurgy included an EPRI-funded corrosion-fatigue study. The study involves the development of a technique to simulate the types of failure observed in operating plant. To aid this research, a loop facility with controlled water chemistry was developed. In addition, the facility has a loading system able to produce cracks on the inside surface of a tube specimen. The results of tests performed in this facility will be used to identify those operating parameters having the largest influence on the corrosion-fatigue failure of boiler tubes in thermal plants.

In 1988, the Department's failure analysis service was concerned with a wide variety of system materials and components. Of particular concern were several instances of fatigue cracking of the high-integrity piping at Darlington and Bruce "B" and corrosion attack on steam generator tubing at Pickering GS. The problem at Pickering later turned

out to be much less severe than was anticipated.

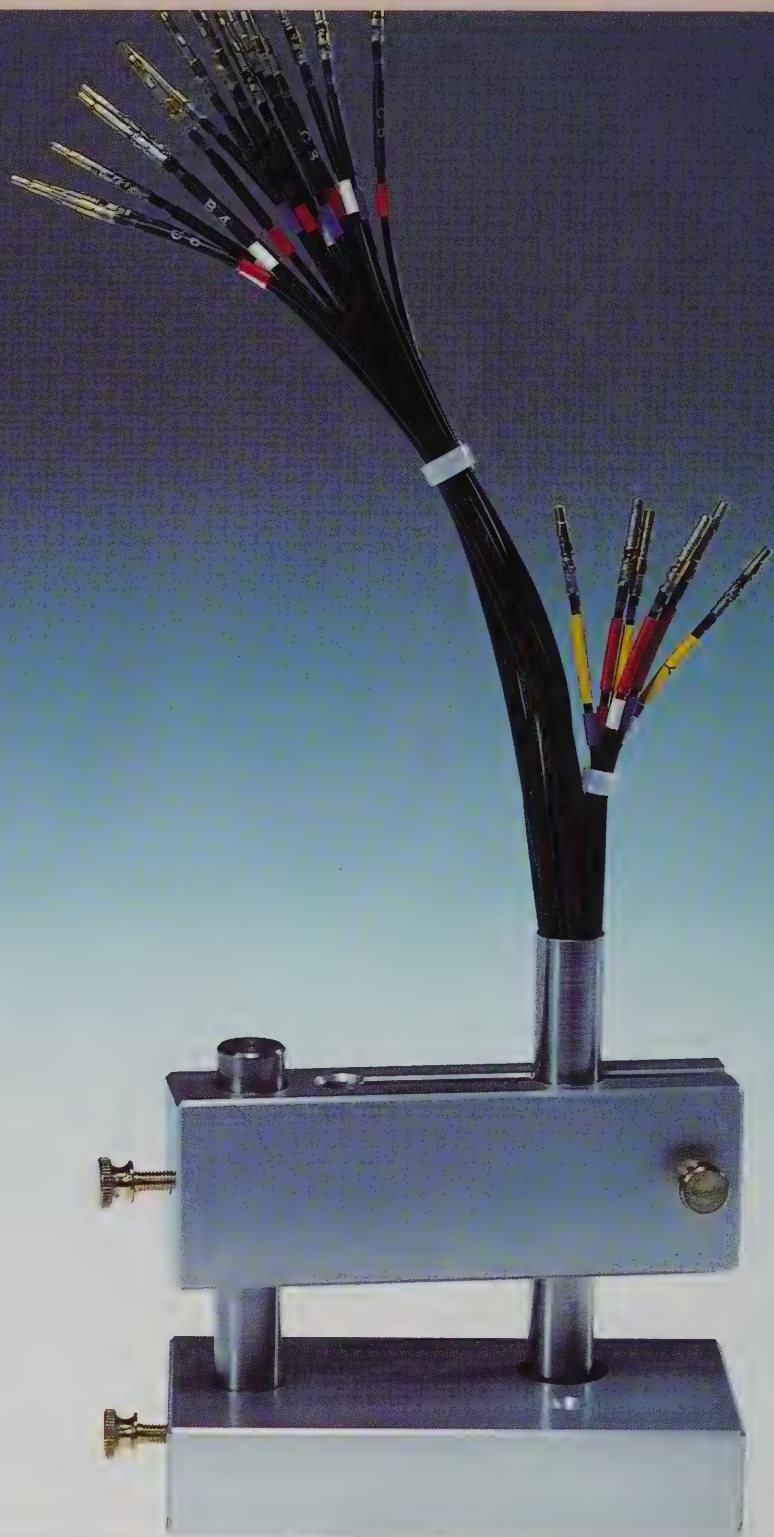
The Welding Unit of the Metallurgical Research Department performs research and development in welding and joining. The Unit is also responsible for the qualification of new and revised standard welding procedures for Corporation use. A major R & D emphasis for many years has been on a CEA, Institut Recherche Electricité de Québec (IREQ), and Research Division effort to develop automated and remote welding methods. An important achievement of this collaborative project has been the creation of a compact robotic system for *in situ* repair of cavitation damage to hydraulic turbine runners. In 1988, work on this system included refinement of the advanced "self-programming" control concepts and the welding procedures used by the system. In addition, the prototype equipment was rebuilt and tested in the field.

Research on welding automation has also advanced in the area of circumferential joints, such as are needed in piping and spent fuel container closures. Special efforts were made last year to improve welding productivity in pipe welding and to optimize processes such as pulsed-gas metal arc and flux-cored arc welding. Technology transfer is always a priority, and to this end, training of field staff in advanced methods was ongoing throughout the year. Excellent results have been reported from field implementation of these methods. A longer-term objective is to define ways in which automated systems can cope with unforeseen variability in joint fitup or presentation. To address this need, experimental work on the use of machine vision is underway.

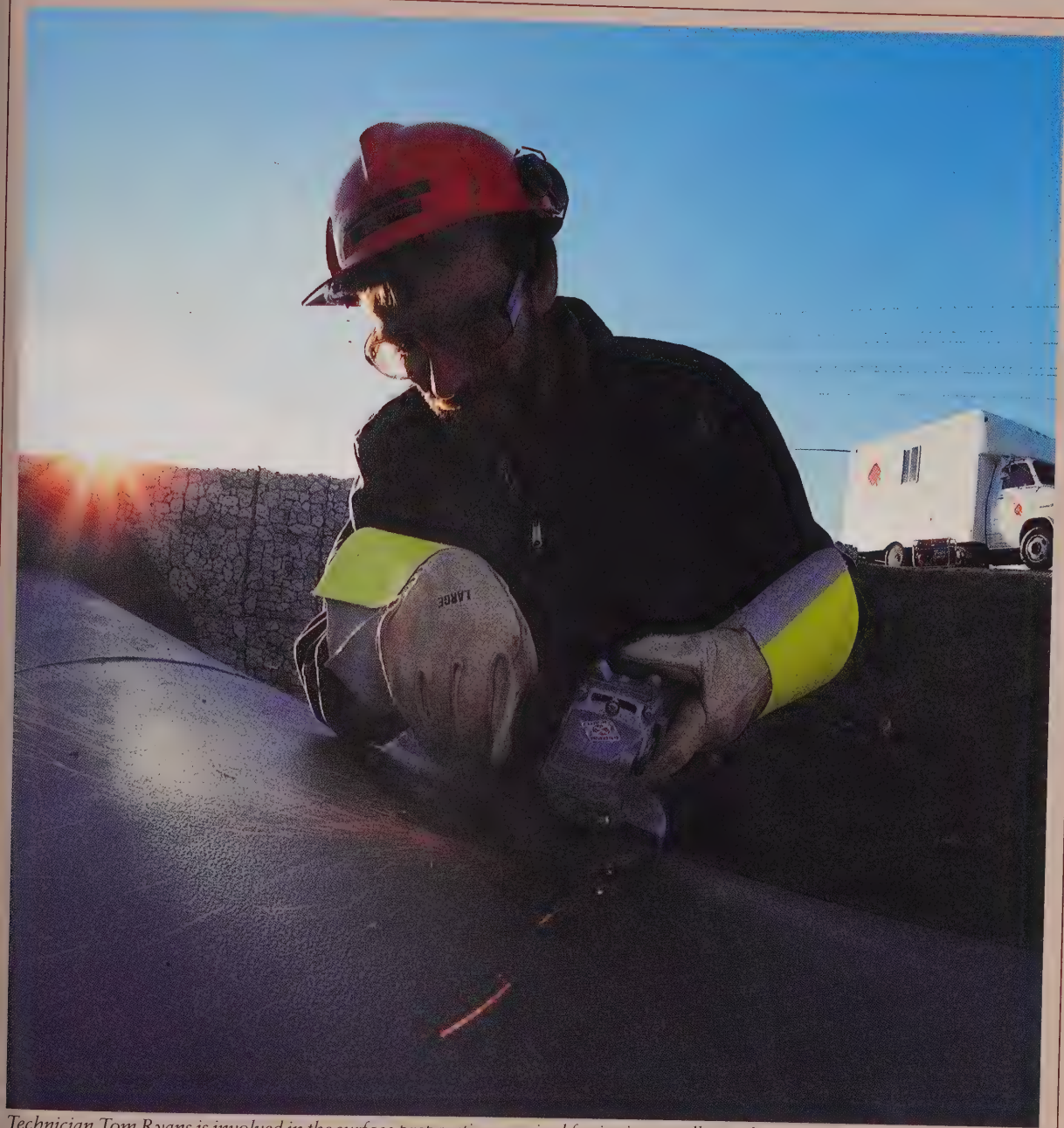
Tritium technology is another active concern of the Department. A new tritium laboratory research and testing facility, equipped with glovebox work stations, protective alarms, and monitors, is almost fully functional at this time. Associated decontamination facilities, clean-up systems, and a tritium supply and delivery system are about to be completed. The safe management and use of an inventory of three kilocuries of tritium can now be demonstrated. Technical support is being provided to the Darlington Tritium Removal Facility, and this includes commissioning and operating assistance, examining the adverse effects of tritium on vacuum pump oils, decontamination of metal components, and exposure testing of a variety of diagnostic devices. Consultation services have been made available to the University of Toronto, the Canadian Fusion Fuels Technology Program, and Hydro's own Tritium Application Program.

A hydrogen pump, which relies on the permeation of atomic hydrogen through bilayer metal membranes, has been developed. There are a number of potential commercial applications of this concept that concern tritium handling and the making of diagnostic measurements in fusion reactor devices. Testing of these is ongoing in the TEXTOR tokamak. Research has also resulted in the development of safe and efficient methods for managing tritium by immobilizing it on high-performance uranium and zirconium-iron getter beds. Some of these beds have already been commercialized. Further work has developed practical systems so that these getters can be used for on-line scavenging of tritium from gas process streams with detritiation factors as high as 10^4 . New alloys such as zirconium-cobalt are also being tested and have the potential to replace uranium for temporary tritium storage.

Finally, a description of two new initiatives introduced



Eighteen-channel multiplexer, which is to be used in underwater service, is being encapsulated in radiation-resistant epoxy. The device will enable many more probes and sensors to be used on the inspection heads of pressure tube inspection systems.



Technician Tom Ryans is involved in the surface preparation required for in situ metallography.

this year to the Metallurgical Research Department: First, the Advanced Industrial Materials Project will be responsible for research into metallic materials required for the continued reliable supply of electricity into the twenty-first century. Work will be concentrated on materials such as composite alloys for fashioning transmission hardware, superconductive materials, and advanced alloys for high-temperature applications in generating plant. Second, a new activity to be developed in support of demand management will examine ways of increasing the efficiency of the metallurgical and materials processing industry. Metals producers

are some of Ontario Hydro's most important customers.

The Metallurgical Department considers itself to be carrying out a successful research and development function. This success is due, in part, to the creativity and innovation that is evident in every undertaking — qualities inherent to the discipline of Metallurgy itself. In this Department, risk taking is encouraged: to try something that does not work is not a failure, whereas not to try it is.

Enhancing Management Effectiveness

Over the years, the Operations Research (OR) Department has assembled a team of highly trained specialists drawn from a variety of disciplines. These specialists carry out a wide range of studies for management, technical departments, and individual researchers. In these studies, scientific methods are applied to complex operational and strategic problems usually related to the management of systems and procedures; men and equipment; materials and money; and data and information. Handling the complexities of these often unusual studies requires the use of a full range of state-of-the-art mathematical methodologies and up-to-date computer facilities.

In 1988, the client base and the range of services offered by the Department continued to expand in areas of decision and operational analysis, statistical analysis, and power system reliability modelling. Services are varied, ranging from informal consultations and short presentations, through large-scale projects, to tailor-made courses and seminars. Additionally, specialized computer application services are made available to the staff of the Research Division.

Operations Research is a label coined in World War II to describe the scientific analysis of military operations. Since then the term has been adopted in business, industry, and government. Increasingly, scientific methods have been used to enhance management effectiveness and operational efficiency. Traditional techniques such as linear programming, inventory control, and queuing theory were always important to management studies, and they are becoming more so



as essential components in the development of decision support systems. Researchers then must be sensitive to the decision environment and must develop innovative new approaches where appropriate. Growing interest in the measurement of intangibles and in complex decision processes provides an additional challenge. Problems often involve several, frequently conflicting, objectives, the ideal solution not always being readily apparent.

In 1988, the decision and operational analysis team achieved a high degree of diversification in areas of consulting and research. Services were provided to several Divisions, including Technical, Training and Services, Controller's, Market Services and Development, Power System Operations, Supply, Real Estate and Security, Transmission Operations, System Planning, Design Development—Generation, Economics and Forecasts, and Thermal and Hydraulic Generation. Some examples of the consulting and research projects are multi-criteria decision analysis for use in finance, system planning, and marketing programs; the application of the integer programming technique to the selection of bids; the development of expert systems to automate procedures as diverse as selecting channels for nuclear fueling studies and assisting in library literature searches; the development of an integrated approach to transmission and generation outage planning; modelling of energy production costs; and the optimization of office planning, design, furniture inventory, and scheduling of physical moves.

Since a reliable supply of electrical energy is part of



Hydro's mandate, accurate reliability predictions for power systems and their constituent parts is a most important engineering task. Equally critical is the assessment of risk involved in many operating situations. In some aspects, the development of reliability methodology based on probabilistic modelling has come a long way in the last 25 years, but it is still not mature enough for use in all applications. The Department's reliability team, however, is at the forefront of the world-wide effort to develop more advanced reliability tools.

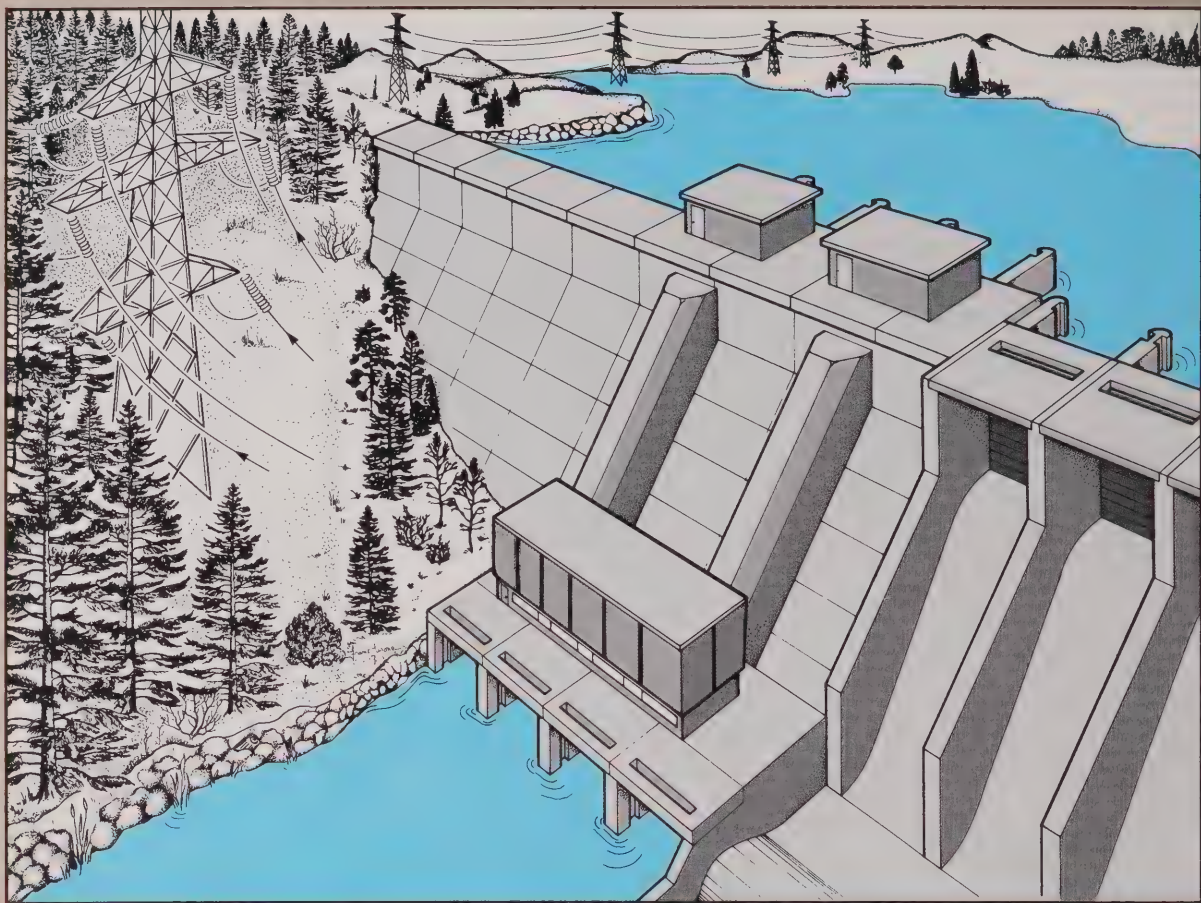
The team's involvement with the development and application of mathematical models for system and component reliability spans almost two decades. The aim of this work has been to assist Hydro's planning, operating, design, and maintenance functions. In 1988, the reliability team continued to engage in developmental work and in the provision of consulting assistance to other Divisions. Important progress has been made in optimization of maintenance procedures, and new concepts and modelling techniques were introduced to represent the processes of deterioration and failure. This year most of the work on the reliability evaluation of the control and operating facilities for the new System Control Centre at Clarkson was completed.

Through their publications and participation on committees and in conferences, the staff of the reliability team have earned an international reputation. This year, staff participated in a number of international technical activities, which included participation in the presentation of a new Power

System Reliability Analysis Application Guide at the 1988 International Conference on Large Electrical Systems (CIGRE) meeting, continuation of industry advisory activities for several EPRI research projects, and the presentation of a week-long seminar on power system reliability analysis at the Xi'an Jiaotong University in China. The seminar was conducted under CIDA sponsorship.

The selection and analysis of data for technical or management studies often appear straightforward and may indeed be so in a simple case. However, when data are scarce, interrelated, dispersed, or even contradictory, the drawing of valid conclusions requires skill and training in advanced statistical analysis. The statistics team was formed several years ago when Corporation-wide need for expert assistance in data collection and evaluation was perceived. Assistance in solving statistical and mathematical problems is provided by the statistics team, whose expertise includes knowledge of sampling schemes, statistical estimation, design of experiments, forecasting, regression analysis, probability theory, mathematical modelling of engineering systems, quality control, and quality assurance.

In 1988, the team performed a number of diverse studies for other Divisions as well as for the Research Division. Studies included the identification of relationships among performance and cost indicators for nuclear and hydraulic sources of energy production; the statistical design of reproducibility experiments for petroleum standards tests; statistical analysis of bursting characteristics of rupture pressure



Current work in the Operations Research Section includes the development of microcomputer-based water allocation models to maximize the output of Hydro's hydraulic generating stations. Station engineers use these computational techniques inter-actively when making decisions about station operations.

relief panels scheduled to be installed at the Pickering NGS; and a proposal for a sampling scheme to estimate the energy saving of retrofitted electrically heated homes. In addition, members of the team participated in the working party on the Environmental and Safety Research Assessment of the CANDU Owner's Group Waste Management Program. Assisting clients through informal consultations continues to be an important part of the team's activities.

Rapid advancement in computer technology provides the staff of the computer support team with a great challenge, and in 1988, the team continued to provide specialized programming and consulting services to the staff of the Research Division. The team also increased its efforts in the research, evaluation, and introduction of new computer technologies. Macintosh facilities with large screens, optical scanners, and high-quality laser printers were purchased and installed for productivity enhancement in report and presentation preparations. Many second generation, integrated PC software packages were evaluated and introduced to staff in the Research Division.

The advancement in computer and information technology has also created a number of opportunities of strategic importance to the effective and efficient operations of

Ontario Hydro. Among them are artificial intelligence and database technology. In 1988, the Department was engaged in the successful development of prototype expert systems. Identification of high payback opportunities continued. The development of uncertainty treatment in machine vision continued as part of our participation in the PRECARN project. Exploratory work for active research in neural networks has begun. Possible applications of this technology to fish identification seem promising. With rapid developments in these new fields, special applications in robotics, pattern recognition, and knowledge preservation and distribution are anticipated in the very near future.

In 1988, the Department was involved in external activities with universities, professional associations, and research institutes. A number of staff members held Adjunct Professorships or served as executives or committee members with professional societies or research granting agencies. Informal collaborative research arrangements were made with universities. Internships were offered to the University of Strathclyde and Glasgow. Staff were also invited to make technical presentations at various universities and industries.

AWARDS AND ACHIEVEMENTS

Under contract with Polysar Ltd., Dr. Hormoz Azizian (Chemical Research) developed new rubber technology at the University of Waterloo. The technology received the 1987 Gold Award of Excellence in the invention category at the Canada Awards for Business Excellence. Already, the new highly saturated nitrile rubber has been earmarked for uses that include high-pressure seals, oil well blowout preventers, gaskets, diaphragms, hoses, tubing, flexible fuel cells, conveyor belting for hot or corrosive materials such as asphalt, and hydraulic system seals and liners.

Carrying on the tradition of excellence started by R. B. Young, a paper co-authored by Tom Carmichael, Douglas Hooton, P. K. Mukherjee, and Val Sturup (all of Civil Research) was awarded the Wason Medal for Materials Research by the ACI. The paper, entitled "Evaluation and Prediction of Concrete Durability: Ontario Hydro's Experience", was selected from among the many papers presented in ACI journals or at conference proceedings during 1987.

Ontario Hydro's New Business Ventures Division selected Dr. H. S. Radhakrishna (Civil Research) as one of its 1988 Product Champions. In the award category of Project Management, Dr. Radhakrishna was recognized for the leadership and coordinating role he played in the successful delivery of Ontario Hydro's Long Island Sound cable crossing project.

Bob Koopmans and Robin Hughes (Civil Research) received a Research Division Director's Award for the development of shallow and deep borehole dilatometers and for the invention of a hydraulic rock breaker tool. The dilatometers are now standard instruments for assessing rock conditions for facilities constructed of rock formations, such as intake or cooling tunnels and nuclear waste repositories. The breaker tool is used by Ontario Hydro in situations in which conventional drilling and blasting cannot be used.

Visitors to the Division now receive a 'Pocket Facts' card that doubles as a name tag. In the Society for Technical Communication (STC) 1988 Competition, two members of the Research Publications Office, Barbara Brown and Lisa Bell (Divisional Services), received an award of excellence for the technical writing and design of this novel promotional material. The STC is the world's largest professional organization devoted to the arts and sciences of technical communication.

The Research Division Annual Report for 1987 won two awards in the 1988 STC Competition. Gary Floyd, Keith Buck, Lisa Bell, and Barbara Brown (all of Divisional Services), Dave Young (Divisional Projects), and Spencer Bush (Information Services Division) earned achievement awards, one for art and design and the other for technical writing.

Greg Stone (Electrical Research), an active participant in the technical and administrative activities of the Institute of Electrical and Electronic Engineers (IEEE), was elected President of the IEEE Dielectrics and Electrical Insulation Society (DEIS) for the 1988-1989 term. DEIS publishes the *Electrical Insulation Magazine*, which has 15 000 subscribers, and a scholarly journal, the *IEEE Transactions on Electrical Insulation*. The society hosts several conferences each year and

is responsible for creating American National Standards.

Dr. Jim O'Neill (Electrical Research) received a U.S. patent for his development of a Waveguide Reaction Cell. The invention is useful for laser isotope separation work.

Wilf Watson, retired Section Head of System Studies Section, Dave Lee, Roger Beaulieu, and Gerry Manchur (all of Electrical Research) received the 1988 W. P. Dobson Award for outstanding technical innovations of benefit to the Corporation and the electric power industry. Developed and implemented were novel excitation control schemes and better models for the enhancement of power system stability. These power system stabilizers have been supplied by Ontario Hydro to locales as wide ranging as Saskatchewan, New Brunswick, and Australia.

The H. A. Smith Award, awarded annually by the Research Division for outstanding contributions that have had a major impact on R & D business, went this year to Dr. Tom Byrne (Mechanical Research) and Dr. Marc Leger (Metallurgical Research) for their research on hydride blister formation in pressure tubes. They undertook a comprehensive research program to determine the consequences of pressure tube / calandria tube contact for Zr-2.5 wt% Nb pressure tubes.

An interdisciplinary team effort of Design & Development Division and the Mechanical and Chemical Research Departments resulted in the invention, development, and demonstration of the 'fish hammer', an acoustical device for controlling fish movement in the vicinity of structures such as generating station cooling water intakes. The combined effort of Dr. Al Christie (Design & Development), Jerry Forest and John Kowalewski (Mechanical Research), and Dr. Paul Patrick (Chemical Research) was rewarded by a U.S. patent and a Research Division Director's Award. The technology is being transferred to a commercial setting.

Dr. Mike Dolbey (Metallurgical Research) was awarded the prestigious Engineering Medal of the Association of Professional Engineers of Ontario (APEO) in 1988. The Engineering Medal recognizes achievements significantly above the normally high standards of the profession. Dr. Dolbey headed a group of engineers and researchers in a project to create special technology to inspect tubes within a CANDU reactor.

The Fracture Mechanics Unit of the Nondestructive and Fracture Evaluation Section was recognized for its analytical and experimental work in elastic-plastic fracture mechanics with a Research Division Director's Award. The research of Dr. Mukul Mukherjee, Bert Vanderglas, Doug Scarth, Olev Lepik, and Dave Carpenter (Metallurgical Research) led to the acceptance of the leak-before-break rationale.

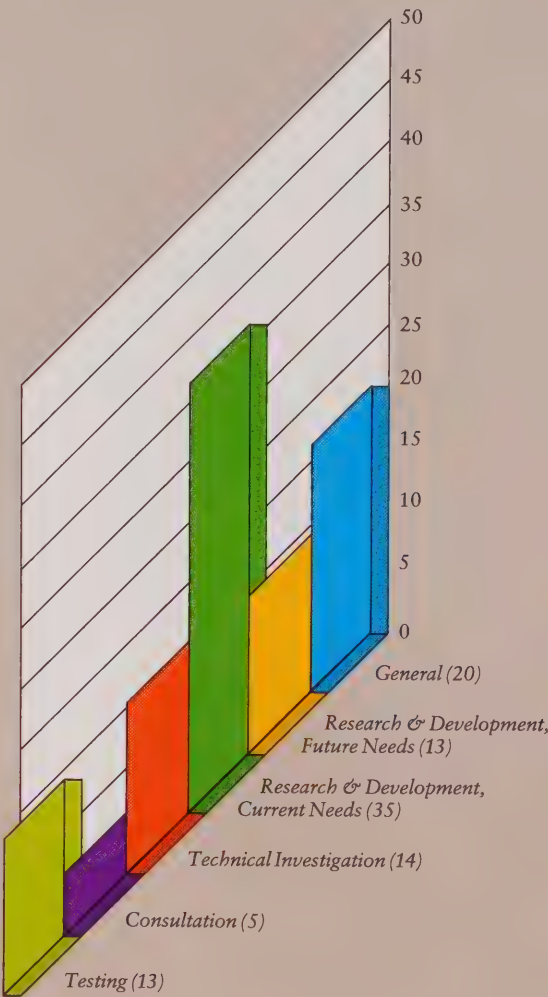
The ICE team, consisting of Dr. Archie Chung, Manager of Operations Research, Dr. Jim Tulk (Mechanical Research), and Alda McMahon (Divisional Services), merited a 1988 Director's Award for its outstanding effort in coordinating inputs, identifying needs, and providing strategies, recommendations, and plans for the development of an integrated computing environment for the Division.

RESOURCES AND COSTS

At the end of 1988, the Division's personnel resources consisted of a total regular staff of 640. The percentages of funds allocated to major work programs and the percentages of program costs attributable to OM&A—the net cost to Ontario Hydro to operate, maintain, and administer the Research Division—are shown below. Also shown are proportions of Research Division costs for various categories of work and distribution of staff in broad occupational classes.

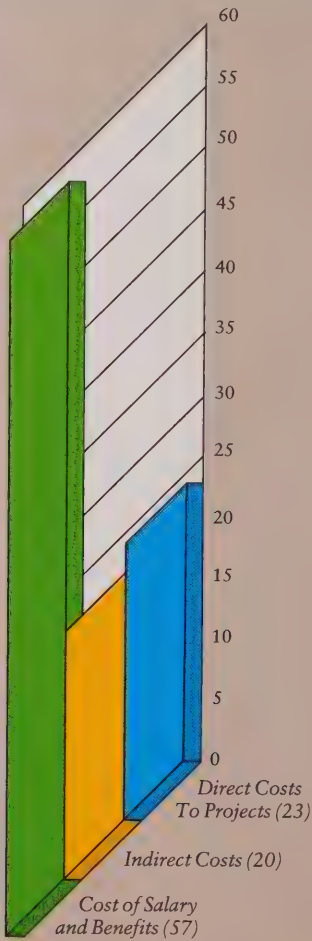
The total of all costs, including those for space, material and equipment, for work done by the Research Division in 1988 was approximately \$68.3 million.

Costs were met or allocated as follows:
Revenue from Work Done for Other Organizations 4
Transfers to Other Ontario Hydro Branches 35
Transfers to the Cost of Power 28

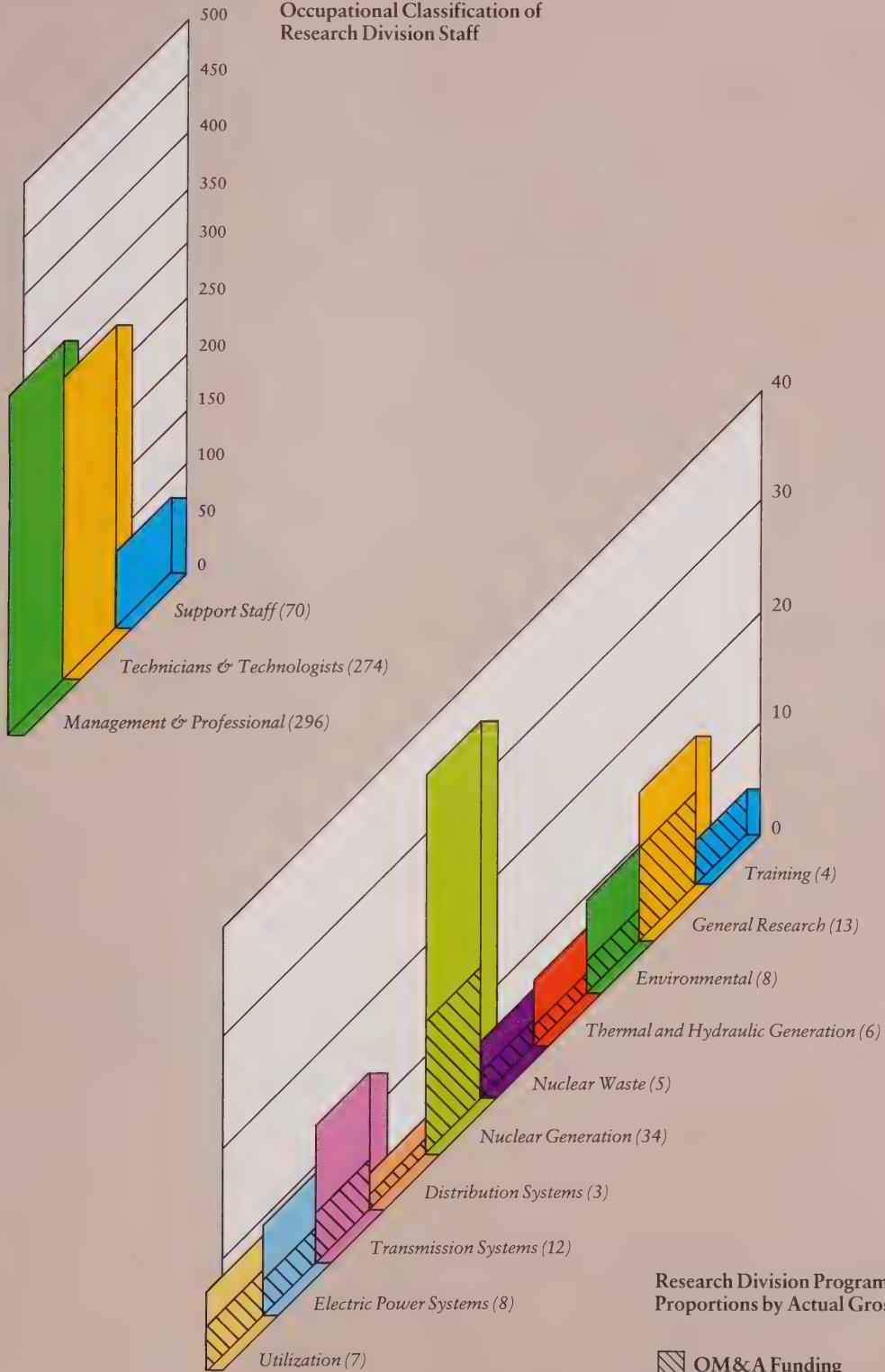


Proportions of Research Division Costs for Various Categories of Work

Research Cost Breakdown by Major Resource Categories (% of Gross Cost)



Occupational Classification of Research Division Staff



Research Division Programs for 1988-
Proportions by Actual Gross Costs

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ACRONYMS

ACI	American Concrete Institute	IREQ	Institut Recherche Electricité de Québec
AECB	Atomic Energy Control Board	MFRRS	Magnetic Field Rodent Reproductive Study
AECL	Atomic Energy of Canada Limited	NDFE	Nondestructive Fracture Evaluation
AI	Artificial Intelligence	NGS	Nuclear Generating Station
AMTU	Advanced Materials Technical Unit (at Queen's University)	NO _x	Nitrogen Oxides
APEO	Association of Professional Engineers of Ontario	NPD	Nuclear Project Demonstration
ASIC	Application Specific Integrated Circuit	NPLA	Nuclear Plant Life Assurance
ASTM	American Society for Testing and Materials	OCMR	Ontario Centre for Materials Research
BEEF	Biological Effects of Electro-Magnetic Fields	OR	Operations Research
BLIP	Blister Location Inspection Package	PHT	Primary Heat Transport
CANDU	Canada Deuterium Uranium (reactors)	PIPE	Packaged Inspection Probe
CDEPTH	Creep Degradation Evaluation in Pressure Tubes (Hydro)	PRECARN	Precompetitive Applied Research Network
CEA	Canada Electrical Association	SLAR	Spacer Location and Repositioning
CIDA	Canadian International Development Agency	SWIPE	Steam-Water Iodine-Partitioning Experiment
CIGAR	Channel Inspection and Gauging Apparatus for Reactors	TAP	Technical Assistance Program (Ontario Hydro)
CIGRE	Conference on Large Electrical Systems	TGS	Thermal Generating Station
CIRAC	Canadian Institute for Research in Atmospheric Chemistry	TWPP	Thin Walled Particulate Packed (container)
CNS	Central Nuclear Services	URL	Underground Research Laboratory
COG	CANDU Owner's Group	WNRE	Whiteshell Nuclear Research Establishment
CPSD	Central Production Services Division		
CSA	Canadian Standards Association		
CUICAC	Canadian University and Industry Council on Advanced Ceramics		
DEIS	Dielectrics and Electrical Insulation Society		
EPCRI	Electric Power Construction Research Institute (China)		
EPRI	Electric Power Research Institute		
FGD	Flue Gas Desulphurization		
GEMS	Generator Expert Monitoring System		
IBSS	Iron Based Stressed Shell		
ICE	Integrated Computing Environment		
ICP	Inductively Coupled Plasma		
IEEE	Institute of Electrical and Electronics Engineers		



From left to right: G. (Gerry) Manchur, D.C. (Dave) Lee, and R.E. (Roger) Beaulieu, all of the Electrical Research Department.

SIGNIFICANT RESEARCH CONTRIBUTION

Ontario Hydro's power system is operating smoothly. To be able to say this of a system limited by its transmission capabilities is to pay sincere tribute to a protracted and intensive research and development effort carried out at Ontario Hydro. Key players are the Research and System Planning Divisions, which, as long ago as the early 1960s, initiated an intensive effort to develop and implement novel excitation control schemes and better models for the enhancement of power system stability.

Since this early effort, work related to power system stability control has come a long way. Each application of a power system stabilizer has resulted in the development of a refined version. By the early 1960s, the first speed-based delta-omega stabilizers were developed for application in hydraulic units. Later application of this design in a fossil-fired station presented problems that further research attributed to torsional oscillations. These problems were resolved, and since then a more efficient stabilizer (the delta-P-omega stabilizer) has been developed.

To maintain stability following severe sys-

tem faults, a transient stability excitation control was developed and installed on major generating units. These innovative designs would not have been possible without the concomitant development of analytical models, such as new mathematical models for generators and their controls. This combination of stability controls has allowed increased power transfer without risk of system instability, thereby saving Hydro's customers millions of dollars.

The significance of this highly innovative research contribution is probably best appreciated only by power system experts. However, the success of the cooperative effort of Research and System Planning Divisions is attested to by its world-wide recognition. Power system stabilizers have been supplied to Saskatchewan, Nova Scotia, New Brunswick, and Australia with consulting services being provided in places as far flung as China and Taiwan. The Hydro approach to power system stabilization is a de facto industry standard, establishing Ontario Hydro as the undisputed leader in power system stability analysis and control.



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Technological insurance is that scientific
and engineering expertise, which,
through research, development, problem
solving, and testing, assures the most
efficient, safe, and reliable power
system for Ontario, now
and in the future.

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VICE PRESIDENT'S MESSAGE

Al Holt, Vice President of Corporate Planning Branch, Don Mills, Director of Research Division, and Harry Kirwin, Station Manager of Nanticoke TGS discuss the optimization of generator performance and reliability.



The 1990s promise to be very challenging for Ontario Hydro. The new problems confronting the Corporation – ensuring that Ontario's rapidly growing electrical demand will be met over the next 25 years, and doing this in an environmentally acceptable way – will create new challenges for the Research Division.

The Division must continue to help Ontario Hydro fulfil its traditional role of providing safe, reliable, electricity for the people of this province. It must also play an increasingly important role in minimizing the impact of Hydro's activities on the environment.

During the past year, system demand reached an all-time high; the Corporation published its 25-year plan, the most far-reaching in its history; and the first steps to transform Ontario Hydro into a fundamentally service-oriented corporation were taken.

The 25-year plan proposes a number of options for meeting power system requirements. Regardless of which option is selected, it will be necessary to maintain and enhance the performance of existing plant as well as to utilize new technologies. The Research Division has a very important role to play in support of these objectives.

To get more out of its existing facilities, Ontario Hydro will have to expand its anticipatory approach to maintenance and aggressive life extension efforts. Products like the Partial Discharge Analyzer and machine vibration monitors will therefore become more important. In the 1990s, as the gap between generating capacity and demand closes, research directed at life expansion of existing stations will inevitably assume more importance.

The long-term plan also calls for new technologies to be used to meet generation needs, and the operating groups within the Corporation will need the support of the Research Division to implement them effectively.

Combustion turbine generators and combined cycle and integrated gasification combined cycle plants are two of the technologies that have been identified. There will be others, in the next ten years.

In addition to its traditional role, the Research Division must address the growing and pressing problem of environmental damage associated with the production of electricity. Research is tackling the issue directly by developing new and better ways to deal with problems such as acid gas emissions and the disposal of ash, PCBs, and high-level nuclear waste. Research also helps increase the efficiency with which consumers use electricity. The less capacity needs to be increased, the fewer the environmental problems there are to solve. A good deal has already been achieved in these areas, but there is much more that can and will be done.

During its long history of support for the operation of the power system, the Research Division has dealt effectively with the various demands placed upon it. I am confident that it will continue to play a vital role in resolving the daunting technical and managerial challenges the Corporation will face in the 1990s.

A.R. Holt

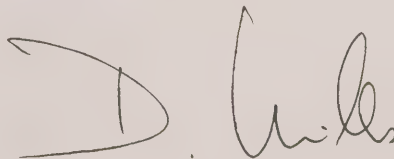
DIRECTOR'S MESSAGE

During the past year, the Research Division underwent a comprehensive review of its organization and productivity. The completion of this process has positioned the Division to meet both the technical and management challenges of the coming decade. Because of the implementation of new technologies and the ever increasing demands being made by our customers upon an aging power system, the scientific and technical support provided to the Corporation by the Division can only grow in importance.

For more than seventy-five years, Ontario Hydro has been investing in the "technological insurance" provided by the products of research and development. This investment has provided benefits in avoided costs and improved reliability that have far exceeded the costs of operating the research function. Indeed, contrary to the traditional view, R&D should be considered a profit-making enterprise rather than an additional cost of doing business. In the coming years, the need to maintain and extend the life of existing facilities and to provide support for new technologies will increase the need for the Research Division to perform its function efficiently and effectively.

In 1989, the Research Division had many opportunities to demonstrate how the Corporation's investment in research has paid off. A number of these examples are described in the theme article, which considers the role of R&D in the provision of "technological insurance" to the Corporation. Topics covered in the article range from the development of a new concrete, through the investigation of the impact of zebra mussels on system operation, to the development and implementation of a novel gas flow measuring device in a nuclear station. It is important to remember that the benefits deriving from this work result as much from the years of investment in the development of expertise as they do from the projects described. Without a continuing investment in anticipatory research, the future needs of the Corporation cannot be well served.

In the past, the staff of the Research Division have risen to the challenges provided by Ontario's power system, by new technologies, and by organizational issues, and through their endeavours, have built an enviable record of success. I would like to thank the Managers of the Research Division and their staff for contributing to this longstanding record of achievement in 1989.

A handwritten signature in dark ink, appearing to read 'D. Mills', with a stylized, cursive script.

D. Mills

SAFEGUARDING CORPORATE INVESTMENT: RESEARCH AND DEVELOPMENT AS TECHNOLOGICAL INSURANCE

Ontario Hydro is entering a critical period. If the reliability and economic price of electricity, a product that Ontarians take for granted, is to be maintained, the very best value must be extracted from every available megawatt of electric power that Ontario Hydro produces. To provide the very best value, the Corporation's generation, transmission, and distribution facilities must be operating reliably at a cost that reflects maximum benefit with minimum expenditure. It is essential that Ontario Hydro meet these challenges because, overall, the province is experiencing a five-percent increase in demand for electrical energy each year. Growth in electrical demand is tied to growth of the economy, so that the long-term trend, in spite of transient fluctuations, will be ever upward.

It is now generally recognized that the economy is becoming increasingly dependent on the successful implementation of a wide range of new technologies. It is fortuitous that Ontario Hydro has always implicitly accepted this fact and has pioneered technological innovation for more than 80 years. This pioneering spirit has led to a successful integration of an in-house Research and Development (R&D) capability with the utility's engineering and operations functions. The integration has paid off: the investment in R&D has provided benefits in avoided costs and reliability of supply that have far exceeded the cost of operating the research function. At the Research Division, effort expended on R&D is viewed as an effective means to protect the Corporation's considerable assets by the provision of "technological insurance".

Ontario Hydro's R&D capability has been further enhanced by the development of links with other organizations and by an active search for funding from other utilities (most notably through the Canadian Electrical Association and the Electric Power Research Institute). A related and useful activity is the forging of links with individual utilities and universities and participation in industrial development projects aimed at solving operating problems. One such problem, which is related to the reduction of SO₂ emissions, is occurring in large electric smelting furnaces. All these activities allow the Research Division to fulfil its mission of providing the very best technological leadership through research and development, which creates opportunities for researchers to help Ontario Hydro meet its goal of supplying reliable power safely and at the best possible price.

A high priority for Ontario Hydro is the protection of its thirty-billion-dollar investment in physical plant. Maintaining the integrity of the utility's nuclear, hydraulic, and thermal stations is important not only in terms of dollar savings, but also in terms of ensuring the optimal functioning of the whole of Ontario's power system in the future. Theoretically, if a potential problem can be identified and the right solution found before it becomes critical, the operation of a generating station can be extended far beyond its planned in-service life span.

The Civil Research Department is heavily committed to making significant life extension of physical plant a reality. In a search for repair materials that can ensure the optimal reliability of generation and transmission facilities, a considerable amount of work has been done on the identification and assessment of the long- and short-term physical characteristics of repair materials suitable for concrete structures.

Placement and handling of materials used in the construction and repair of transmission lines always presents a challenge. The perfect material would allow a field worker to mix it, place it, and walk away from it. When repairs are needed in remote locations, such as in northern Ontario, these three criteria are of inestimable importance. Ironically, winter is the best time to carry out transmission line construction and repair because frozen ground makes access for heavy machinery easier. Severe winter conditions, however, cause serious problems in the placement of concrete foundations since normal Portland cement will not develop strength under cold temperatures unless costly and time-consuming concrete curing precautions are taken. These precautions include preheating the rock surface for 24 hours and then, when the concrete is placed, covering the repair area, and keeping it heated for three days in order to properly cure the concrete. The value to Ontario Hydro of a concrete that could be placed without such measures is significant.

As a response to this need, in collaboration with a local manufacturer, a polymer-based concrete was developed. The material was revolutionary. The very-low-temperature concrete properly cures and develops its full strength at temperatures as low as -25°C without the need for heating and housing.

The material was developed over the period 1986 to 1988, with its first application beginning in late 1987. The concrete is expected to have significant and wide ranging benefits not only for Ontario Hydro, but also for the construction industry at large.



Repairs to concrete foundations of transmission towers contribute to an increase in their lifespan. Repairs have been greatly facilitated by the development of low-temperature concrete.

The low-temperature concrete obviates the need for costly provision of heat, thereby shortening dramatically cold weather concrete placing schedules. Construction flexibility is improved, and project costs are reduced, both of which serve to benefit builders and customers. Of benefit specifically to Ontario Hydro was a six-month reduction in the overall schedule required to construct a transmission line between Hanmer and Mississagi transformer stations, a distance of 200 kilometres. The material has also been used to replace deteriorating concrete footings on energized transmission lines within half a working day.

Tangible benefits to the Corporation are significant. Two million dollars were realized to date, with future savings over the next several years expected to be in the hundreds of millions. External to the Corporation, this innovative concrete has made its mark. It has been used successfully in bridge construction and maintenance and in other major construction projects in North America.

A dam failure has the potential to harm lives and towns, as well as the environment. Additionally, the cost of lost power attributable to dam failure could be considerable. The importance of a system that can give early warning of potential dam failure is obviously important. The monitoring systems being developed by the Civil Research Department will make it much easier for staff to react to, and resolve, a problem before it becomes serious. New electronic monitoring instrumentation being designed in the remote monitoring project will replace those local monitoring systems currently in use. Once completed, newly developed instrumentation will provide automatic, immediate, and continuous data that can alert off-site staff to potential problem areas. Successful implementation of these systems at hydraulic stations will provide engineers and technicians with timely information on the behaviour of dams and ensure that these facilities will continue to be available for electricity generation.

Another process that impacts significantly on ensuring the continued reliable operation of generating plants is the corrosion-induced degradation of critical components. Particularly at risk are steam generators and heat exchangers, and significant and successful work on the understanding of the corrosion process as it relates to these components has been ongoing for a long time.

Work on steam generator corrosion actually began in the mid-1970s. At that time, although Ontario Hydro's steam generators were giving outstanding performance, the rest of the world was beginning to have problems with these components. It was recognized that, although the utility's steam generators were operating well, the global situation was giving early warning of the risk of similar problems developing.

In the Canadian Deuterium Uranium (CANDU) system, steam generators represent the thinnest and largest surface area of the primary system pressure boundary. Failure of this boundary could lead to heavy water leaks and consequent shutdown as well as to



A field inspection of concrete footings is in progress. Non-destructive test equipment allows in situ inspection of the foundations.

early repair problems. In addition to leakage, fouling of steam generators or their support structures could cause unit deratings, which would incur major economic penalties. Reliable steam generator performance is therefore essential. The approach to warding off potential problems is comprehensive, and research in this field has concentrated on two main areas. First, work to optimize system chemistry by isolating and defining the consequences of unexpected changes in chemistry on system integrity was carried out to prevent reliability problems from occurring. Second, chemical methods have been developed to remove corrosion-inducing deposits, if these were to become of concern to operators.

As part of corrosion studies on steam generators, Alan McBride, chemical technician, injects chemicals into a high-pressure autoclave to remove oxygen in the solution.

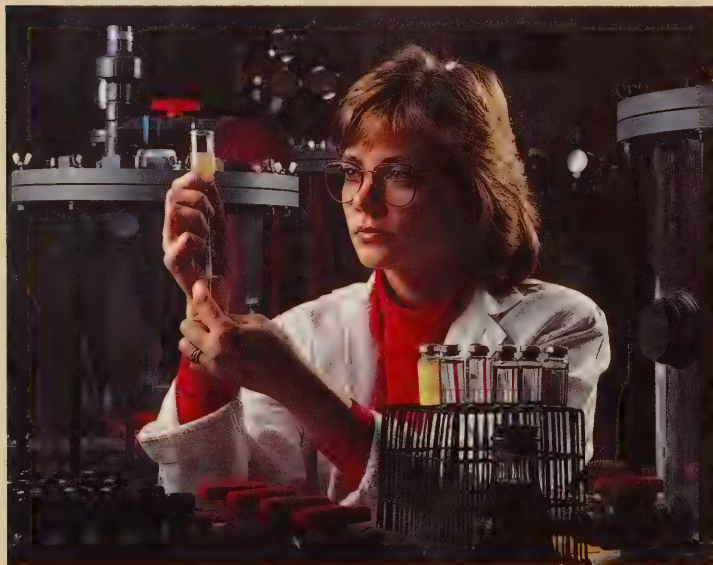


More recently, the importance of biological activity in the corrosion damage of heat exchangers has been undergoing close scrutiny. Corrosion of these components has the potential of contributing not only to increased operating costs, but also to the cost of replacement energy and for materials needed to replace heat exchanger components.

The biological factor is only one aspect of what appears to be a complex multidisciplinary chemical, biological, and physical interaction, which becomes active in the corrosion process when new heat exchangers are first exposed to lakewater. At this time, the heat exchanger is readily colonized by microorganisms. Proliferation of these organisms and an accumulation of organic and inorganic materials lead to the formation of a biofilm on metal surfaces, which facilitates subsequent breakdown of the protective oxide layer. Pitting and under-deposit corrosion can occur as a result. Sulphate-reducing bacteria (SRBs) are frequently implicated as causal agents.

The recognition of the importance of microorganisms in heat exchanger corrosion failures prompted the initiation of two major research projects. The two projects, which began in 1989, share the objectives of increasing understanding of the role of biological factors in the corrosion process and in determining ways to reduce the amount of corrosion. The first project will determine whether the surface modification of heat exchanger materials increases resistance to corrosion; the second will determine the role of anaerobic microbes in the pitting of heat exchanger materials. A successful research outcome will reduce the risk of failure attributable to microbially influenced corrosion. The potential benefits are substantial reductions in capital and operating costs for heat exchanger systems at both nuclear and fossil-fired generating stations. Technology transfer could extend these benefits well beyond Ontario Hydro into the private sector, a concomitant effect being an advance in corrosion control technology. Both projects will be conducted under accelerated test conditions. Corrosion activity will be monitored by using electrochemical techniques in conjunction with subsequent surface analysis.

Irene Cord, biological researcher, counts sulphate-reducing bacteria (SRBs) in a culture. SRBs are frequently implicated as causal agents in the microbially-influenced corrosion processes.



In the laboratory, metal samples, including some surface modified materials, are exposed to accelerated corrosion conditions by immersion in cultures containing sulphate-reducing bacteria. The samples are removed for testing and surface analysis at predetermined intervals. It is expected that surface coatings will influence corrosion rates by changing the extent of biofilm adhesion, by modifying the electrochemical properties of the metal surface, and by presenting a physical barrier to aggressive chemical and bacterial species. The resulting data should provide a clear indication of the role of surface modification in reducing corrosion rates and microbial attachment.

The intensive laboratory component of the surface modification project is to be complemented by a field component. In the field study, heat exchanger tubing, treated in the same way as the laboratory samples, is to be placed in a test rig that simulates conditions within a moderator heat exchanger. The resulting data will permit comparison of laboratory results with those obtained under actual operating conditions.

Multidisciplinary problems require multidisciplinary approaches. Consequently, involvement in the study team is wide ranging, involving water chemists, biologists, corrosion experts, and electron-optics specialists. The project also involves close collaboration with the Chemistry and Metallurgy Section of Central Production Services.

Ontario Hydro's operation is being threatened by an unusual problem. An exotic species of mussel has been introduced in the Great Lakes. *Dreissena polymorpha* (the zebra mussel), a common freshwater bivalve of European origin, was introduced into Lake St. Clair in 1985. The organism, undoubtedly introduced as a result of discharge of ballast water from a European ship, will, if uncontrolled, foul the water intakes of Ontario Hydro's generating plants situated on the Great Lakes. The problem is one with which the European power industry has been wrestling for many decades.



Biologists inspect rocks at Mohawk Point on Lake Erie. As suspected, the zebra mussels have spread along the northern shore of Lake Erie within one growing season.



Since its introduction into Lake St. Clair, the zebra mussel has spread rapidly to the Detroit River and the Western and Central Basins of Lake Erie, as far as Port Maitland. The species has already reached Lake Ontario, and its ultimate spread into the rest of the Great Lakes and inland waterways appears inevitable. As a response to this escalating and potentially serious situation, the Biological Research Section of the Chemical Research Department has been participating in a concerted multidisciplinary effort to ensure that remedial strategies were in place prior to the organism's arrival at Ontario Hydro's generating stations.

Without proper control, the mussel will undoubtedly colonize parts of Ontario Hydro's water intake structures, which will result in detrimental effects that include severe restriction of cooling water flow in generating plants. Additionally, their growth or the impingement of shells on condenser and heat exchanger tubing may diminish plant performance through blockage or degradation of heat transfer. A concomitant problem may be the corrosion-inducing anaerobic bacterial activity that may occur underneath excrescences of the zebra mussel.

Once established, zebra mussels spread quickly. By May 1989, the Chickenolee Reef, an important spawning ground for whitefish and walleye, was 90 percent covered by a single layer of mussels and, by October, was totally buried three layers deep. The loss of this reef and others like it could herald the loss of walleye and whitefish as commercially valuable species. More ominous for Ontario Hydro's operation is that, by the spring of 1989, mussels had already begun to show up in the intake pipes of eight municipal water treatment plants on Lake Erie, the Detroit River, and Lake St. Clair. By October, the intake capacity of the pipes was down twenty five percent. The pipes, some of them, six kilometres long, will have to be replaced at a cost of \$1 million per kilometre.

As no universally acceptable method of controlling the mussel exists, and the need for mitigating action is immediate, information from research studies is urgently needed to develop a control strategy. Currently, a successful dispersal monitoring program is in place that allows early detection and subsequent tracking of the mussels' progression. By September 1989, the organisms, at the settlement stage of their development, were identified over the intake valves of Ontario Hydro's Nanticoke power station, which is situated at the east end of Lake Erie. Monitoring blocks submerged in the forebays of the station indicated that infestation was at a density of 100,000 mussels per square metre. Ontario Hydro's Environmental Protection Department had anticipated their arrival and had installed fine mesh screens across internal pipes. At this settlement stage, however, the mussels are minute, approximately 0.2 mm in length (no larger than the tip of a pen), so that they can easily pass through most fine strainers. Further inspection confirmed that colonization in service water piping and in fire protection systems had taken place. Intermittent control treatments began in October.

Zebra mussels settle one on top of the other. The resulting thick layer can create major clogging in water systems infested by the species.



Divers inspect zebra mussel-infested rocks offshore. Determination of distribution at various depths may help in the development of strategies to preclude infestation of stations.

To supplement the use of monitoring blocks, plexiglass sidestream samplers, with growth chambers, have been designed for use in each station. These transparent boxes contain removable plates that are fabricated from materials used in the construction of generating plant and from materials known to be favourable for mussel attachment. If mussels are present in any system, they can be readily detected upon examination of the plates.

To develop an effective control strategy for the zebra mussel, an extensive knowledge of its ecology and physiology is required. A breeding colony is being established in the laboratory for use in long-term studies designed to provide information on the organism's response to currents, temperature, pressure, turbulence, and thermal shock. Simultaneous field studies will collect data on depth distribution, reproductive habits, growth, seasonality, and substrate preference. Although it would appear from initial studies that at least several aspects of the biology of *Dreissena* in Lake St. Clair resembles European populations, the findings will need verification. This research is being conducted in conjunction with the University of Guelph.

The current practice of using various chemicals to control mussel populations may not be approved by the Ministry of the Environment for continuous use. And even if a few chemicals are approved, they will have to be thoroughly evaluated with respect to their potential effect on other organisms. Alternative controls are being investigated, and these include ozonation, filtration, anti-fouling coatings, and use of electric fields. As each type of control has limited usefulness, it is likely that total control will involve a combination of various technologies.

The work on the zebra mussel clearly demonstrates how a research capability and active research in a variety of areas provide the Corporation with a "technological insurance policy". This policy will ensure that few surprises occur with attendant major failures of the bulk electricity system and that, when crisis situations arise, effective support is available to quickly provide ways to correct the situation. The research and development work can be viewed as an activity designed to protect the Corporation's assets. In this light, research and development can be seen as a major underpinning of the province's future economic growth.

Judy Kwik, biologist, determines the density of mussels on rocks at Mohawk Point. The rate of growth of mussels can be determined by changes in their size and structure.





Instrumentation and monitoring systems have been installed in hydraulic stations to facilitate assessment of their condition, which, in turn, determines maintenance needs in a timely manner.

Ontario Hydro's nuclear facilities are not exempt from scrutiny. Like other types of power plants, nuclear stations are susceptible to aging. Even the aging of Darlington, not yet fully in service, must be taken seriously because, when this station is on line, nuclear power will account for fully 60 percent of the utility's total energy production.

When compared to their original design life of 40 years, Ontario Hydro's nuclear power plants are relatively young, the oldest commercial plant being approximately 17 years old. By the year 2000, however, several units will be approaching "old age". Thus the question of maintaining safety and reliability of aging nuclear plant is becoming increasingly important. Yet, age-related degradation of plant components is a complex phenomenon not yet fully explored.

It is fortunate then that expertise developed at the Research Division has found useful application in a most important multidisciplinary Nuclear Plant Life Assurance (NPLA) program. The overall program is designed to address uncertainties about age-related degradation of plant components so that potential problems can be identified and resolved before any loss of safety or reliability of supply occurs. The program draws on expertise from six of the Research Division's departments, the overall program being directed by an inter-divisional steering committee with representatives from Design and Development, Nuclear Generation, and Central Production Services Divisions.



Mark Tinkler and Murray Mathers of the Research Division and IREQ's Jean-Luc Fihey look on as Hydrobot, a portable robot developed jointly by Ontario Hydro and IREQ, repairs cavitation damage on a turbine runner.

Research Division efforts directed toward ensuring the optimal performance of Ontario Hydro's nuclear plant are covered by two elements of the NPLA program. One element is committed to assure the life of nuclear plants during their normal service life of 40 years; the other element concerns life extension, which provides the option of extending the life of nuclear plant beyond normal service life.

The first step in the NPLA methodology is to divide plant components – a nuclear plant has thousands – into two categories, critical and noncritical. Noncritical components are those that can be easily and economically replaced and critical ones are those that are neither easily nor economically replaced, the failure of which would impact negatively on the safety, reliability, or life expectancy of a plant. Based on specific selection criteria, the list of critical components is prepared and includes items such as fuel channels; steam generator; the calandria vessel, its supports and cooling system; primary and secondary heat transport system; vacuum building; and cables.

The second phase of the program serves to identify what needs to be done. For each critical component, necessary initiatives are formulated to achieve an understanding of aging mechanisms, an early method of detection and prediction of age-related degradation, and a means of restoration of lost performance.

The decommissioning of the Nuclear Power Demonstration (NPD) nuclear station after 25 years of operation provided the NPLA program with an excellent opportunity to examine naturally aged plant components and materials. Since the plant components at NPD had been exposed to their operating environment longer than components in any other CANDU plant, their examination will be invaluable in the identification of aging mechanisms not yet encountered in younger stations.

During 1989, several research and development programs were identified as being necessary to support the NPLA program. The thrust of these programs was to assess the effect of service-related degradation mechanisms on materials used in the manufacture of critical components. The goal is to devise a standardized evaluation procedure to monitor and predict the remaining life of nuclear plant components.

For example, assessment of fatigue damage and evaluation of fatigue crack growth and metal weld degradation are expected to be aided by the development of a data base of the properties of materials. Similarly, the extensive use of cables has given rise to another area in which new research and development initiatives have been identified. As a response to the critical nature and significant cost of installing cables, a program has been proposed to develop techniques to monitor and assess cable degradation and to predict remaining life. One technique under consideration will be to develop cable jacket materials that will indicate through an obvious colour change whether the materials have been exposed to damaging conditions.

The reliability of Ontario Hydro's plants is also enhanced by the development of sophisticated diagnostics, which allow determination of the actual condition of electrical equipment such as generators,

motors, transformers, and switchgear. Appropriate diagnostics can warn operators of incipient problems well before a forced outage occurs, thereby allowing timely corrective action to be taken to minimize the impact on the power system. Some types of generator problems can be detected years in advance of actual failure, which permits maintenance measures to be planned in an orderly fashion, often at a fraction of the cost of a repair made on a reactive rather than on a planned basis.

Specific diagnostic instrumentation that has been developed to date at the Research Division includes a Partial Discharge Analyzer that can evaluate the condition of stator insulation in hydraulic generators. A similar technology is being evaluated for detection of comparable faults in turbine generators, the monitoring of which has been much enhanced by a novel application of laser-based phosphor thermometry technology. A nitrogen laser puts out pulses of ultraviolet energy, which are then delivered by an optical fibre to excite a phosphor-resin mixture painted on the surface of the rotor. The resulting visible fluorescence is then picked up by a second optical fibre and transmitted to a detection system external to the generator. The light passes through a filter to isolate a particular emission line, which is then detected by a photomultiplier tube.

Silvano Rizzetto of Electrical Research monitors an ultra-sensitive detection system that is used to test epoxy insulators used in gas-insulated switchgear.



To make the most effective use of new and extensive conventional sensor data, a Generator Expert Monitoring System (GEMS) is being developed that incorporates advanced knowledge of machine operation to correlate the data and make recommendations concerning the condition of the turbine generator.

Data collection and analysis are performed by a microcontroller-based system that first synchronizes the pulsing of the laser and the rotation of the rotor, so that the laser acts like a stroboscope to illuminate one spot on the rotor, and that subsequently determines temperature by evaluating the decay time of the phosphor emission by comparing it to a calibration table. This novel diagnostic tool can give generator operators information to which they are currently not privy: namely data on temperature at specific locations along the length of the rotor. This will give advance warning of localized hotspots attributable to overheating of rotor insulation. This information can be used to prevent untimely equipment failure.

Laser technology is an important component of another piece of important work ongoing in the Research Division: the work allows measurement of the flow of annulus gas within the CANDU reactor. First, an explanation of the annulus gas system.

In the calandria of the CANDU reactor, pressure tubes containing nuclear fuel and hot pressurized water are surrounded by an annular space through which dry, chemically inert gas is flowing. Taking advantage of the presence of this dry gas provides the basis of a safety feature unique to the CANDU system. Continuous monitoring of the gas for moisture is important diagnostically because the presence of moisture in the gas could indicate a leak in a pressure tube, the detection of which permits automatic shut-down of a reactor.

In order to be able to monitor for moisture, it is necessary that gas flow be maintained in the annular space around each individual pressure tube. The ability to verify that flow is present, and at what rate gas is flowing, can assure the very highest level of leak detection.

To assure long-term reliability, an ultra-sensitive detection system has been developed to test epoxy insulators in gas-insulated switchgear.



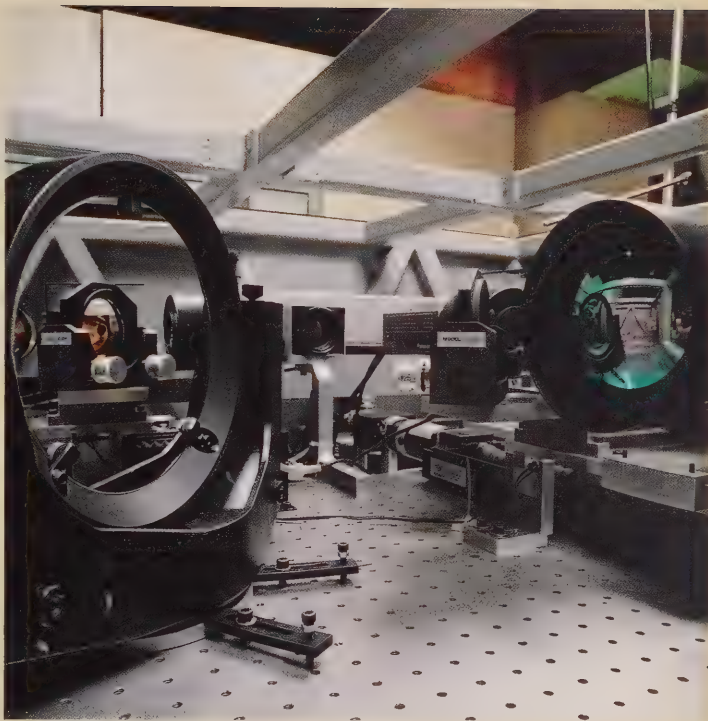
In addition to the safety concerns that could exist if a means of monitoring the flow of annulus gas were not available, there is also a hypothesis that, if pressure tubes are not subject to adequate gas flow in the annular space, they may demonstrate a higher rate of pickup of hydrogen than would otherwise be the case. Since hydrogen pickup is thought to be the factor that causes pressure tubes to become brittle, which results in expensive retubing operations, the validity of the theory is important.

During the past year, Pickering Unit 3 was scheduled to be shut down for retubing operations. The situation provided researchers with a unique opportunity to prove or disprove the theory that relates to the relationship between hydrogen pickup and pressure tube embrittlement. This is because Pickering 3 could have all its tubes analyzed for hydrogen content after their removal. However, to make sense of this data, it was imperative that the annulus gas flow rate in each tube be determined before the reactor was dismantled and retubing began. If the annulus gas flow rate at Pickering 3 had not been measured before the dismantling operation began, the information leading to an understanding of the correlation between annulus gas flow and hydrogen pickup would have been lost forever.

It was fortunate that a method of measuring gas flow in the annulus existed, at least conceptually. The original concept involved heating a "pigtail" with an electric heating element. Pigtails, so-called because their purpose of connecting the fuel channel gas annuli together sometimes required that they be looped around the channel to allow for expansion, were then photographed with a heat sensitive camera. In the laboratory, it was shown that, if gas were flowing, the hot spots appeared asymmetric.

In practice, however, there were many obstacles to overcome. The major problem was one of access. The annulus gas flow has to be measured within the CANDU reactor, a difficulty compounded by the fact that the reactor face is extremely congested with a forest of equipment. Additionally, pigtails are sometimes two metres from the closest point that can readily be accessed with measuring equipment. The objective was to build a non-invasive tool capable of measuring gas flow in all the pigtails of Pickering 3 reactor channels prior to the retubing operation, which was scheduled at the outset of the project to begin in mid-October 1989.

Early in January, a team was assembled. The work, funded by Central Production Services Division, required a wide range of internal expertise. This expertise was drawn from the Research Division, Nuclear Systems Department, Supply Division, and Design and Development Division. The basic idea had been undergoing some refinement. To overcome the access problem, a highly focused carbon dioxide laser was proposed to heat up designated pigtails. When the laser beam was removed from the designated spot, the infrared camera could be used to detect the presence or absence of flow. The concept was further refined by the addition of image processing to measure the extent to which the hot spot had been affected by flow, thereby allowing a quantitative measure of flow.



Fifteen years of laser and optics experience were applied to refine the concept further. A computer was used to continuously capture and analyze the infrared image of the cooling pigtail. Another important development was the addition of a helium-neon laser collinear with the infrared laser. This development allowed the production of visible red light, which allowed the infrared laser to be more accurately aimed at the pigtails by operators. The final addition of a steerable mirror for fine positioning of the laser obviated the design problems associated with attempting to position the whole assembly with the required accuracy.

In the laboratory, the refined design allowed flow rates inside tubes to be easily measured down to flows as small as 100 ml per minute. In the station, however, a major problem arose. Whereas in the laboratory good measurements of flow rate could be obtained with analysis of data taken over a 175 mm segment of tube, in the field the much shorter 25 or 50 mm of pigtail available for observation made getting good results very difficult. Over a period of several months, many different approaches to the problem were taken, but with little success. Diligence and hard work, however, paid off in the end when, after trying over 50 different computer algorithms, one was found that allowed reliable measurements to be made on small data sets.

The heart of the annulus gas thermography tool consists of sophisticated modern optics and lasers, such as the computer-steerable mirror, infrared camera, and CO₂ laser shown here.



The laser thermography tool control allows operation of the tool from outside the reactor vault.

Equipment was built, tested, and commissioned before the imposed deadline. It weighed approximately 1 500 kg, was to be approximately 1.5 x 3 x 0.5 metres in size, the whole assembly to be mounted on a lift. The equipment was operated remotely, some two metres away from the reactor face. A mockup of the reactor was also required to train personnel how to use the equipment. The mockup was built in just six weeks in the Central Maintenance shops, much time being saved because a design already existed. Atomic Energy of Canada Limited (AECL) made drawings available that had been developed for the Pickering retubing project.

The project was successful, and though the results are still being analyzed, they are expected to be far reaching. The project as a whole attests to what can be accomplished with a good team and the necessary expertise.

In what is expected to be an exciting and challenging future, Ontario Hydro will continue to meet its traditional goals of supplying its customers with reliable power at the best possible price. To help ensure that these goals are met, the Corporation has been investing in R&D for over 75 years. This investment has paid off during these years. The expertise made available by the Research Division has benefited both the Corporation and its customers, and the Research Division will continue to expend its effort to provide the Corporation with what amounts to a technological insurance policy. The examples of current work ongoing in the Research Division that have been described in this article give some insight in the scope of its activities. The Division's future effort, through to the next century, will be to capitalize on innovation through R&D as a means of building on Ontario Hydro's strengths and of safeguarding a sizeable Corporate investment in physical plant.

Through
excellence,
innovation, and
internationally
acclaimed research,
we will be
leaders in the
introduction
of new
technologies
to
Ontario Hydro
and the
electrical industry.

CHEMICAL RESEARCH: MANAGER'S OVERVIEW

The Chemical Research Department provides the Corporation with a technical resource that includes process and materials chemistry, chemical analysis, biology, and environmental science. A staff of approximately 140 chemists, chemical engineers, biologists, and highly skilled technicians conducts research, performs technical investigations, promotes energy efficiencies in the chemical industry, and offers problem solving services related to the chemical, biological, and environmental aspects of electric power generation. Specialized experimental facilities and state-of-the-art instrumentation for measuring and analyzing experimental parameters are used in this work. Comprehensive chemical analytical services, which support the research programs of the Division as well as the Corporation, are also provided.

"Chemical Research's staff, sophisticated equipment, and directed research programs are essential ingredients of the Corporation's technological assurance package"

Dave Dodd, Manager



Technical staff, ongoing research programs, and sophisticated departmental facilities and equipment provide the necessary ingredients for the provision of innovative ways for Ontario Hydro to identify and prevent problems and to respond quickly and effectively to them, if and when they arise.

Almost one-third of the Department's resources support the Corporation's nuclear commitment. Work ranges from research on maintaining steam generator tube integrity to work on developing nuclear waste management options. A containment leak test using a tracer gas technique and an ultrasonographic method was developed and used successfully at Bruce NGS "A". This capability was used to demonstrate to the Atomic Energy Control Board (AECB) the performance of the vault cooler fans and hydrogen ignition systems at Darlington NGS.

Prevention of worker exposure to radiation and hazardous substances is addressed by research programs that range from development of respiratory equipment for workers, to component and full-system decontamination processes. An alternative to the discontinued Stephenson respirator for protecting against tritiated water vapour was developed in collaboration with manufacturers, and as part of this project, alternative sorbents and prototype respirators were evaluated. Studies of the tritium behaviour with non-metallic materials are conducted to select protective barriers for use as gloves and suits and to develop decontamination methods.

As long as the process chemistry is properly controlled, the CANDU Decontamination (CANDECON) process for decontamination of heat transport systems is successful. The Department's expert analytical capability and experience in decontamination process development played a major role in providing monitoring for the successful decontaminations carried out last summer in Pickering Unit 3. A collaborative effort with Central Production Services Department and AECL-Chalk River to develop and qualify a dilute oxidizing pre-treatment for end-fitting decontamination resulted in the first full-system application of the process. Work with the University of Guelph will allow greater understanding of the mechanisms of oxide dissolution and corrosion during decontaminations. A successful outcome will help ensure that appropriate and reliable decontamination technology is available to the Corporation.

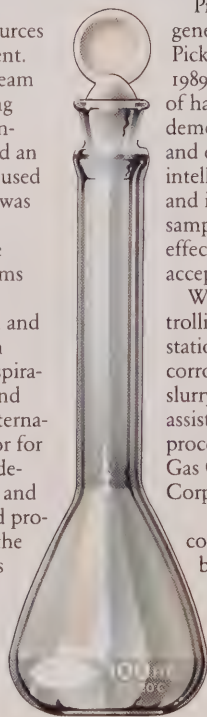
In the nuclear waste area, the Department is involved in an extensive program to monitor the performance of a concrete integrated container designed to transport and store spent fuel. A two-year demonstration is underway at Pickering NGS. After a suitable decay period, low- and intermediate-level radioactive wastes may be treated more economically as non-active wastes. The Department is monitoring the effect of long-term storage on waste packages, packaging materials, and engineered storage structures in the laboratory and in the field. Research has been performed to identify potential chemical hazards in radioactive wastes and to develop immobilization methods.

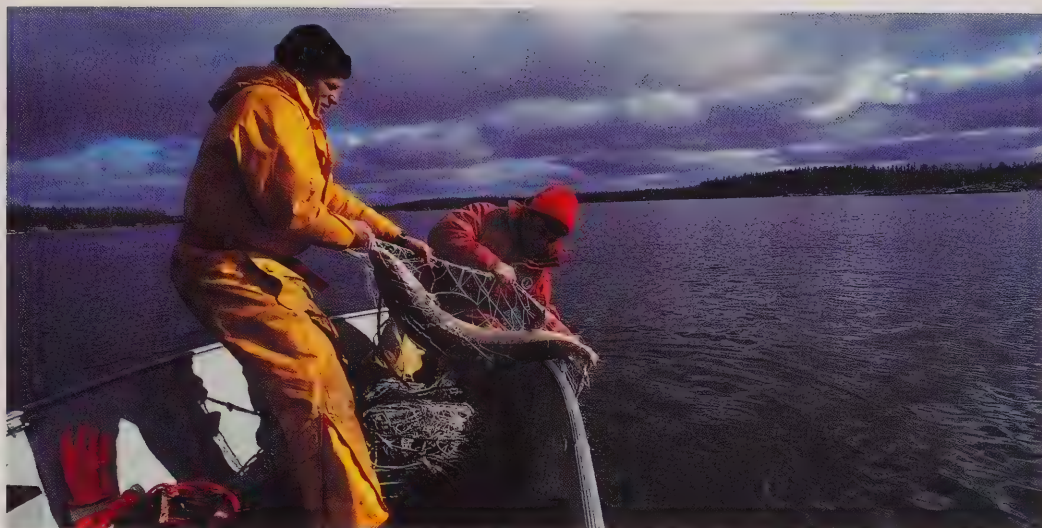
Chemical research supports the Corporate goal of developing and managing its activities and facilities so as to protect the environment. Areas of work range from monitoring the effects of Ontario Hydro's operations on ecosystems to developing new means of emission control.

Pre- and post-operational studies of the effects of generating facilities on the aquatic environment at Pickering and Atikokan are almost complete. In 1989, a technique to verify spawning and the date of hatching of round whitefish was successfully demonstrated. Techniques such as radiotelemetry and enhanced sonar systems, coupled with artificial intelligence techniques, are being developed to track and identify fish. Such non-consumptive and remote sampling systems will make future surveys more effective, less costly, and environmentally more acceptable.

Work in support of Ontario Hydro's plans for controlling acid-gas emissions from thermal generating stations includes studies of reagent regeneration, corrosion, and gypsum production in the limestone slurry or dual alkali processes. The Department has assisted Design and Development Division in the process selection and tendering phase of the Acid Gas Control Program and in the acquisition of FMC Corporation's limestone dual alkali technology.

The Combustion Research Facility, at which the combustion characteristics of different coals can be evaluated, has proved invaluable as a site for the development of a sorbent injection system for simultaneous removal of SO_2 and NO_x .





Biologists Scott McKinley and Henry Kowalyk of Chemical Research are tagging a lake sturgeon in the Mattagami River as part of a study to determine the effects of the operation of hydro-electric stations on the existence of the species.

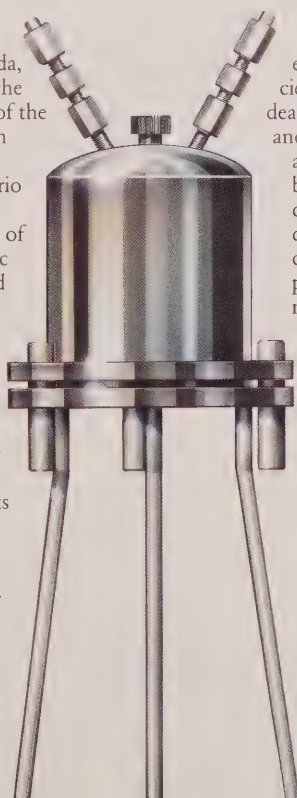
This facility was recently upgraded with a new coal-grinding and pneumatic feed system and a new sophisticated electrostatic precipitator able to collect dusts from low-sulphur fuels or in-furnace additives. The precipitator will enable researchers to help Ontario Hydro fulfil its environmental responsibilities in a more efficient and cost-effective manner.

The Department continues its search for solutions to the problem of handling PCB-contaminated wastes. The work includes the development of decontamination procedures for PCB-contaminated transformers, evaluation of PCB-replacement insulating fluids, and investigation of chemical PCB-destruction methods. During 1989, staff represented Ontario Hydro in a consortium that organized the first Canadian demonstration of a mobile PCB incinerator at Swan Hills, Alberta. This consortium included Environment Canada, Hydro Québec, the Québec Ministry of the Environment, and the Ontario Ministry of the Environment. A successful demonstration and subsequent approval for commercial operation in Ontario would permit Ontario Hydro to destroy its PCB-contaminated wastes. The quantification and resolution of problems associated with leaching of toxic preservatives from the thousands of wood poles used and stored by Ontario Hydro is another example of an environmentally related study.

Whereas the foregoing relates to the environmental impact arising from the generation, transmission, and distribution of power, concerns about the natural environment's effect on these same systems is also of concern. Pollutants in the atmosphere are contributing to the corrosion of Ontario Hydro's older transmission lines, and a major refurbishment program is planned. Studies are underway

to identify the pollutants and the meteorological conditions affecting these lines. Historical and environmental data obtained in the field will be used to map the corrosivity of the atmosphere and to estimate the remaining life of transmission lines. Other work to assure the reliability of the transmission and distribution system includes a study of the role of freezing rain and fog in the occurrence of flashovers on the 500-kV transmission system. The search for more effective methods of controlling tree growth on transmission and distribution rights-of-way continues, with the objective of reducing herbicide use.

The Department's work program also supports the Corporation in numerous other ways. Assessment of the performance of organic materials used in electrical equipment and throughout the generation system; an effort to develop and introduce more efficient electrochemical processes; and work dealing with understanding climate change and the effects of electric and magnetic fields are some of these. In addition to the direct benefits derived from new technologies developed in the programs that have been described, the skills and capabilities developed at the forefront of technology provide a critical component of the technological assurance required by the Corporation. The Chemical Research Department is committed to help the Corporation meet Ontario's need for electrical service in a safe, reliable, and environmentally responsible manner.



The Civil Research Department of Ontario Hydro's Research Division has been a leader in civil engineering technology for over seven decades. Departmental expertise, which includes key areas such as concrete technology and quality control, provides vital support in the construction of new facilities. Specialized geotechnical engineering support to the Division and to the Corporation as a whole is also provided.

In the Department's role of serving the research and development needs of the Corporation, projects have ranged in time and scope from the construction of Ontario Hydro's early hydraulic stations to the current construction of a world class power project, the Darlington Nuclear Generating Station.

The expertise of the Department is essential to the Corporation's Dam Safety Program. Working as a multidisciplinary team, the various sections of the Department provide services to evaluate the integrity and to monitor and assess the performance of the Corporation's hydraulic structures.

To satisfy regulatory requirements, in-service inspection of concrete components in Ontario Hydro's nuclear structures is ongoing. In support of this program, laboratory studies are being conducted. One program is an investigation that will allow better understanding of the mechanisms of loss of integrity of concrete due to leaching of its solutes when exposed to flowing deionized water. Understanding of these mechanisms is applicable to studies of containment concrete used for irradiated fuel storage bays. The durability of concrete in freezing and thawing environments is being investigated when the concrete is simultaneously under the influence of a thermal gradient and when one boundary of the concrete surface is covered with an impermeable membrane or a repair material.

The quality of concrete aggregates and their sources is reviewed periodically for suitability for use in new construction or in the rehabilitation of existing structures. Such a review includes detailed laboratory testing of aggregates to identify potential problems with respect to alkali-aggregate reactivity or to various aspects of concrete durability. A specific application of these procedures is the development of the high-density concrete used in the construction of containers designed for dry storage of nuclear waste. The applications of these procedures are widening; they help assure both the minimum density of concrete needed for radiation shielding and the moderately high strength needed to ensure structural integrity.

Additionally, the Concrete Control Section provides on-site inspection and testing of concrete and concrete materials for major construction projects such as the Darlington Nuclear Generating Station. Inspection and testing are also provided for rehabilitation and reconstruction of smaller hydraulic, thermal, and transmission projects.

The Civil Research Department participates in the development of national and international standards on concrete and related areas. This activity keeps the Departmental staff abreast of advances in the field. Such participation has been recognized through citations and awards received by some staff of the Concrete Technology Section.

"Research and development can ensure the structural integrity and the continued safe and reliable performance of Ontario Hydro's generation and transmission facilities"

Tony Klym, Manager



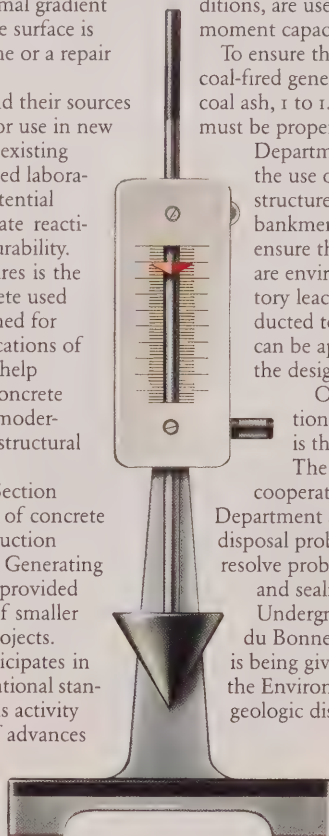
The Soil Sciences Section performs field and laboratory measurements of soil properties, which include shear strength, consolidation, dynamic behaviour, and hydraulic parameters. Experimental research work dates back to the 1950s and has produced a centre of expertise on the thermal properties of soil materials. Thermal properties are essential when determining the best backfills to use when placing underground power cables.

Transmission tower foundations must resist a wide range of compression, uplift, and lateral loads. To provide reliable, cost-effective support for the design and construction of these structures, the Soil Sciences Section carries out full-scale tests on a wide range of foundation types, including steel grillages, drilled piers, piles, grouted rock anchors, helix anchors, and grouted soil anchors. State-of-the-art design methods, derived from instrumented full-scale tests in various soil conditions, are used for determining the uplift, lateral, and moment capacities of foundations.

To ensure the smooth operation of Ontario Hydro's coal-fired generating stations, the large quantity of coal ash, 1 to 1.2 million tonnes produced annually, must be properly managed. For many years now, the Department has carried out studies to support the use of large volumes of fly ash in concrete structures, in the construction of highway embankments, and in land reclamation projects. To ensure that the utilization and disposal of fly ash are environmentally acceptable, field and laboratory leaching and geochemical tests are conducted to study leaching properties. The results can be applied when formulating guidelines for the design of disposal or storage sites.

One of the requirements for the operation of Ontario's nuclear generating stations is that nuclear waste be disposed of safely.

The Civil Research Department works in cooperation with the Nuclear Engineering Department and AECL to develop solutions to waste disposal problems. Major projects are underway to resolve problems related to excavation disturbances and sealing of underground repositories in the Underground Research Laboratory (URL) at Lac du Bonnet, Manitoba. Essential technical support is being given to AECL in the preparation phase of the Environmental Impact Statement on deep geologic disposal of nuclear waste.





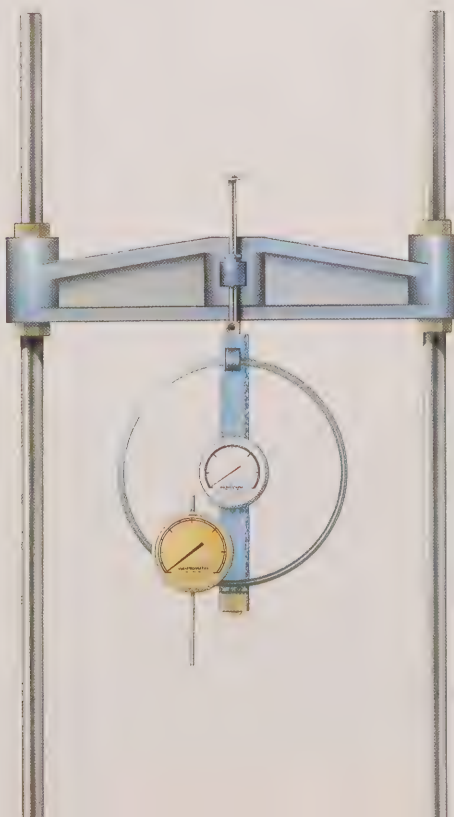
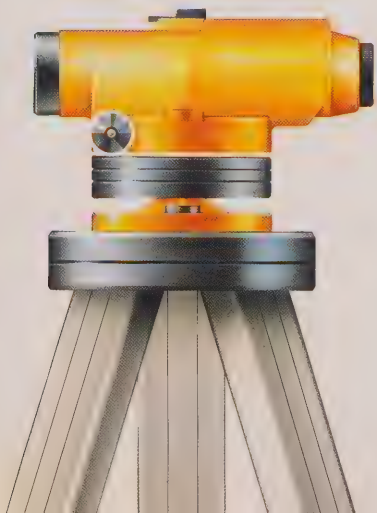
Jim Sato and Ken Hare are monitoring moisture migration through concrete structures. The project, selected to receive Director's fund support, will determine the durability of concrete and repair systems.

Clay-based buffer and backfill materials to be used in the URL project are being assessed in the Soil Sciences Section for their thermal hydraulic properties and their long-term performance. A one-eighth scale concrete model of a proposed repository design was used in the study of the near-field thermal regime. This work was done as a forerunner to the proposed full-scale URL experiment.

The Rock Sciences Section determines the mechanical properties of rock masses, which are essential for the design, construction, and evaluation of underground structures and foundations, as well as for the safety assessment of hydroelectric dams. In situ testing for the determination of rock modulus, stress, strain, fluid pressure, and convergence or deformation in rock is being routinely carried out. In situ measurements are usually preferable to laboratory measurements because they account for large-scale features of the rock mass. A number of in situ techniques have been developed. Automation of geotechnical instruments and telemetering of data from remote dams are important components of dam safety.

Hydrogeology and environmental geochemistry work focuses on field and laboratory investigations of leakage pathways from, and into, underground structures, evaluation of the isolation efficiency of engineered barriers, and the assessment of contaminant migration. Radionuclide sorption and diffusion properties of geomaterials and concrete are being determined in a radioactive materials laboratory.

These essential services of the Civil Research Department provide state-of-the-art technological assurance in support of the Corporation's mandate.



DIVISIONAL PROJECTS: MANAGER'S OVERVIEW

The Divisional Projects Department provides an interface between divisional staff and various groups within the Corporation as well as with groups external to the Corporation. The Department's major products are new technology initiatives, research management studies, and research business support.

For many years, the Research Division's mandate has been to support Energy Management Branch in its efforts to help industry use electricity wisely and to assist customers to find and implement competitive industrial processes. The Divisional Projects Department serves this dual purpose by developing new technology initiatives.

The Process Metallurgy Project continues to expand its commitment to better energy management, and a number of research programs are currently addressing issues of load reduction and potential load shifting. In addition, study efforts are assessing the impact of alternate metal refining processes with the objective of reducing CO₂ levels. The industrial effectiveness issue is being addressed through projects such as one being done in collaboration with Metallurgical Research Department and Falconbridge Limited. The project is aimed at solving operating problems that occur in large electric smelting furnaces as a result of attempts to reduce SO₂ emissions.

The Department is committed to increasing awareness in industry of the potential of laser-based processes now under development in the Research Division. Laser-based developments are quickly becoming accepted and used to advantage in the US, Europe, and particularly in the Pacific Rim countries, the greatest source of competition for Canada. The vehicle for disseminating this information is the Canadian Industrial Laser Association (CILA). CILA came about as a result of the efforts of the Divisional Projects Department. The Association has already had a number of meetings, and a managing executive has been set up. The organization boasts a strong industrial base and a strong sense of commitment.

The Research Division seeks to improve its effectiveness and efficiency by collaborating with external organizations. As part of this collaborative effort, Departmental staff, particularly those involved in new technology area, exert a strong influence on Canadian universities and industrial R&D. Influences are brought to bear through the acceptance of adjunct professorships at local universities by Research Division staff; memberships on industrial advisory councils, such as the Canadian University - Industry Council for Advanced Ceramics (CUICAC); the Ontario Centre

for Materials Research (OCMR); and the Centre of Excellence in Laser and Lightwave Research. Additionally, Departmental staff sit on Natural Sciences and Engineering Research Council (NSERC) funding committees and influence university curricula through council memberships.

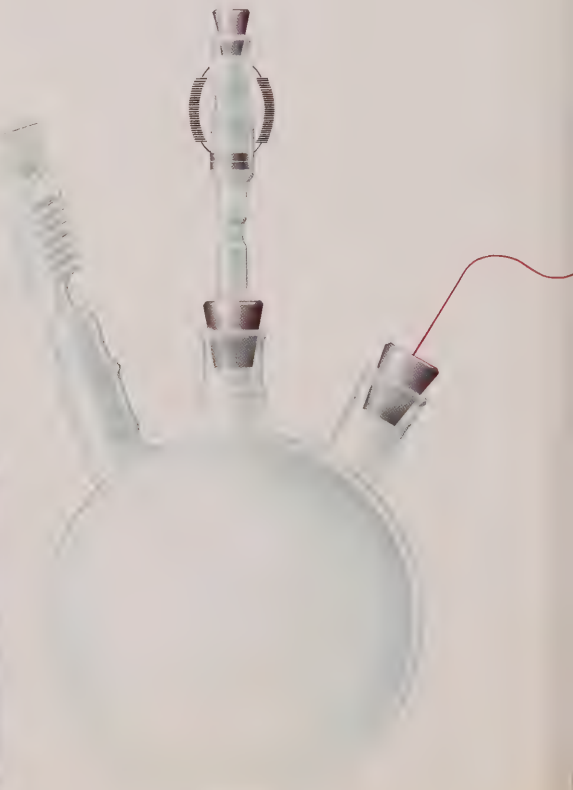
This year, the Divisional Projects Department coordinated the production of the Division's business plan, and additionally, it played a lead role in the Division's annual strategy setting session. The business plan, which communicates the Division's future plans to senior management, provides direction for staff responsible for detailed work planning that spans a period of ten years.

The Division's business plan for 1989-1998 stressed the importance of providing "technological insurance" to protect the Corporation's thirty billion dollar investment in sophisticated physical plant. The plan made clear that research, specifically anticipatory research, is a necessary activity for the maintenance of this asset base. As a response, to provide the funding and the type of environment required for innovative research, a Director's Fund was established. Divisional Projects Department assumed the task of developing and administering this program. In 1989, six projects were selected from over thirty proposed by Research Division staff.

Part of the Department's responsibility lies in identifying opportunities to improve research management. Currently, research management studies are looking at the impact of computers on the way work is conducted.

"The Division's capabilities are enhanced through anticipatory research, new technology, external business relations, and research management studies"

Mikk Anyas-Weiss, Manager





Technicians are tapping hot metal from a pilot electric furnace at Lakeview TGS. The furnace, built at Research Division, will be used to optimize the performance of Ontario's smelters and melters and to investigate new processes and products.

The identification and reporting of "Notable Accomplishments" also falls into this area. Notable accomplishments are R&D projects of significant benefit to the Corporation, the customers of Ontario Hydro, or some identifiable third party. Such reports are produced every five years and clearly demonstrate that the benefits provided by the Division significantly exceed the total costs for a specific five-year period.

Technology forecasting is important for research management. General long-range planning forecasts are provided biennially for the Research Program Advisory Committee. Forecasts are conducted to explore the probable development of specific technologies and their potential impact on Ontario Hydro. Assessments of the impacts of advanced industrial materials and high-temperature superconductors are two examples of recent forecasts.

The Divisional Projects Department also carries out the very important Directorate support function. This year, the Department arranged and coordinated a Divisional Open House. It was attended by over 2000 visitors and provided the basis for some very positive comments about Ontario Hydro in the Provincial Legislature. The Department also assisted the Director with numerous presentations, senior management meetings, and with initiatives such as the modernization of the auditorium. The Research Division Awards Program is another important way of fostering and rewarding excellence within the Division. The awards program for 1989 was organized by the Department and held at the Airport Marriott Hotel.

The Department continues to provide support in the area of external contracts. Activities included liaison with Law and New Business Ventures Divisions, development of contracts and agreements, development of requests for proposals, and the production and monitoring of information related to financial aspects of contracts.

In support of the Divisional external contract function, the Department provides a monitoring function by scanning external publications for contracting opportunities.

In addition, the Department maintains and updates information on the Division's capabilities in a number of externally-based databases.

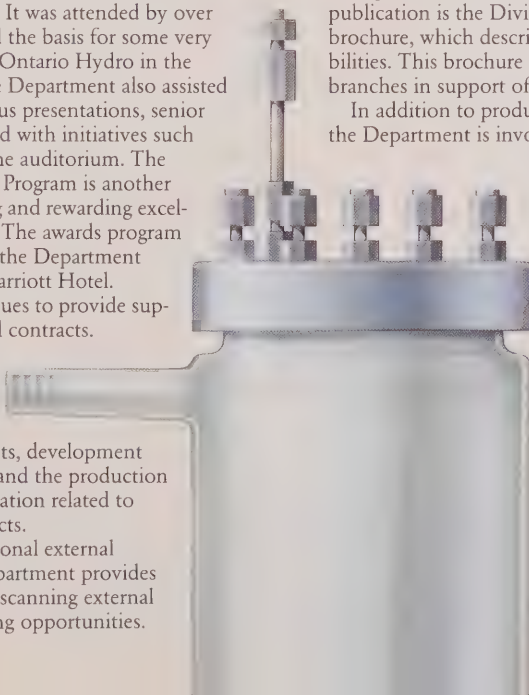
In support of the Division's business activities, the Department assists in the planning and hosting of technical conferences. Examples are the recent meetings of the Canadian Industrial Laser Association, Conference on Large Electrical Systems (CIGRE), the Electrochemical Spring Symposium, and Institute of Electrical and Electronics Engineers (IEEE). Other activities include arranging training sessions for clients of New Business Ventures Division, development and deployment of special displays, and arranging events to promote the Division to external organizations.

The Department is involved in the identification and development of communications. Perhaps the most important of these is the Division's Annual Report, the document you are reading now. The Department assembles the text, coordinates the editorial activities, and arranges for artwork and printing. Another significant publication is the Division's Services and Capabilities brochure, which describes the Division's R&D capabilities. This brochure is used extensively by other branches in support of their marketing activities.

In addition to producing written communications, the Department is involved in the production of videos that describe the activities of the Division.

One such video, for visitors and new staff, has been produced this year, and another, which deals with the contribution of Ontario Hydro and the Research Division to the growth of Ontario, is being planned.

The communications produced by the Department are of a high calibre. They have won a number of awards from organizations that specialize in industrial communications.



DIVISIONAL SERVICES: MANAGER'S OVERVIEW

"Excellence is achieved
through the commitment
and abilities of
our people"

Bruce Brown, Manager



This year, the Divisional Services Department achieved its objective of providing excellence in service to Ontario Hydro's Research Division. Services were many: those offered included business administration; financial reporting; payroll; records, space, and safety management; printing and clerical services; report production; model shop production; drafting; photography; and editorial services. Additionally, significant strides have been made in the Integrated Computing Environment (ICE) project.

The Model Shop continues to upgrade and strengthen its support capabilities. New equipment and tooling was acquired this year. With higher accuracy as a goal, machines were replaced, numerical control was introduced, and all machine axes were equipped with linear encoders. Accordingly, emphasis was placed on meeting the needs of the Division more efficiently, as well as on meeting some of the more stringent requirements of the Design and Construction Branch, the CANDU Owners Group (COG), Canadian Electrical Association (CEA), Electrical Power Research Institute (EPRI), and Central Production Services Division (CPSD). To date, the prototyping service has made a significant contribution to both the Spacer Location and Repositioning (SLAR) and the Channel Inspection and Gauging Apparatus for Reactors (CIGAR) programs.

The Integrated Computing Environment Section has taken on the responsibility for the delivery of computer communications, technical computing, and voice messaging services. Before ICE could deliver its services to the Research Division, a suitable design was required for the installation of network cabling and electronic components. Finalizing a design was not easy because of the wide variety of tenant needs, the rapidly evolving communications industry, and the electrically noisy environments that exist within many Divisional laboratories. This year, however, a suitable design was finalized and Divisional employees can look forward to devices that will allow their personal computers to be networked with others, both within and outside the Corporation. A voice messaging service means that colleagues can be contacted quickly via an automated telephone-answering service. A wide variety of office automation, data manipulation, and technical problem solving tools will allow larger Divisional business goals to be achieved economically and efficiently. The anticipated benefits

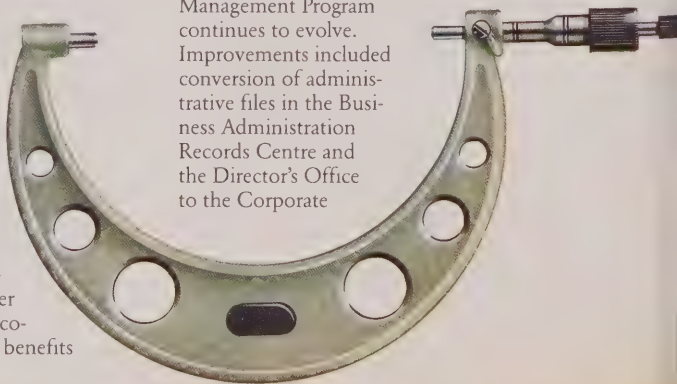
of the ICE initiative are increased productivity plus real financial savings resulting from the ability to share the use of costly computing resources. The payback period on the investment required to install the ICE network is expected to be within twelve to fifteen months of completion, which is scheduled during 1990.

The Drafting Section continues its long-term commitment to deliver the very best in drafting, design, and illustration to Divisional staff. Consistency, precision, and innovation are necessary to produce quality drawings and prompt revisions. Innovation in ways of producing quality designs and illustrative graphics is the hallmark of this Section. Extensive use of Mac II and AutocAD systems allows emphasis to be placed on timely accommodation of the Research Division's internal clients. Additionally, the Drafting Section prepares drawings and provides ideas for drafting and design graphics for both the Division and the public. High quality technical illustrations grace the Research Annual, and mural designs improve the decor and work environment of the Division. The Drafting Section's work impacts not only on effective visual communication, but also on morale.

The Photographic Services Section has had another hectic, but successful, year. Video productions ranged from one targeted at the new employee to another promoting the Division's work internationally. "Affirmative Action - Women for the Future", "Fusion Energy" [a World Energy Conference/Canadian Fusion Fuel Technology Program (CFFTP) Production], and most recently, "GEMS", Generator Expert Monitoring System (produced for EPRI) are some other examples of fine video productions.

The Research Publications Office continues to produce the Research Annual, which last year won accolades from many, most notably in the form of a Society for Technical Communication achievement award. "Chit Chat", the Division's informative newsletter, was redesigned and, based on a user survey conducted this year, is playing an important role in enhancing communications and boosting morale. Desktop publishing capabilities now allow the office to play a significant role in the production of the Division's Business Plan. A number of communications courses for staff of the Division were thoroughly investigated by a member of the office staff, and suitable courses were subsequently recommended to the Research Executive. Finally, a report database, which has been under development for some time, is now functional, and plans to transfer it either to the Hydro mainframe or the ICE network have been initiated.

In the Business Administration Section, the Records Management Program continues to evolve. Improvements included conversion of administrative files in the Business Administration Records Centre and the Director's Office to the Corporate



Frank Turone of Research Division's Drafting Section works at a computer terminal. Extensive use of Macintosh II and AutoCAD systems allows timely accommodation of Research Division's clients.



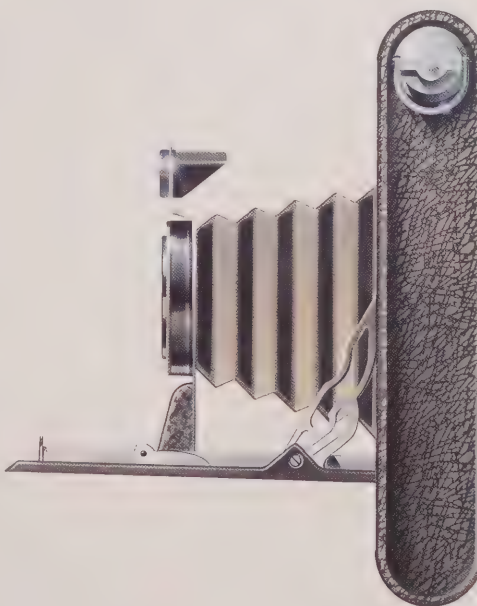
General Subject Index. Additionally, technical files in the Radioactive Materials Laboratory are eighty-five percent converted and expected to be completed by year-end. Approximately forty boxes, i.e., over eighty-three feet of inactive files from central records were reviewed and either marked for destruction, given new retention periods, or identified as having archival value. A presentation was given to key personnel on how to use the revised administrative filing index to its potential. Further presentations are planned before year-end.

Information Management has continued its commitment to provide secretarial and telecommunications support to Research. The Word Processing Centre provides a relief service by filling secretarial positions in the Division. Additionally, short-term clerical and filing help can be provided as required.

The Health and Safety Section ensures that line management provides a healthy and safe work environment. It also provides guidance to the technical sections on environmental matters, such as pertain to laboratory waste disposal, spill control, and releases of airborne substances into the environment.

Legislative pressure and Corporate obligations have raised issues related to hazardous material management. Most departmental effort was directed at ensuring compliance with Workplace Hazardous Materials Information System (WHMIS) legislation. To date, all chemicals in the Division have been inventoried and all laboratories have WHMIS boards and supplier Material Safety Data Sheets (MSDS) in place as well as a set of Divisional workplace labels prepared for containers of chemicals. All Divisional staff have received training, and a video-based training program is being completed for future use.

Another health-related issue pertains to the considerable effort spent on ensuring compliance with the Corporate code of practice on accident and incident reporting. Several incidents with high-to-medium potential for harm were investigated. Other major activities assisted in, or carried out, by the Health and Safety Section are initiation of hazard identification training; respiratory protection training; workplace inspections; and consultations for other Research Division Departments. All in all, a successful and busy year for Divisional Services.



The question of the long-term security of an increasingly complex power system that operates under severe externally-imposed constraints deserves serious attention. This is particularly important when new technologies are needed to meet power system growth requirements.

In 1989, a substantial portion of the Electrical Research Department's efforts was therefore invested in the development of a better understanding of aging and failure mechanisms and in the implementation of new diagnostic techniques and protection systems.

Reliable protection of power system components, such as generators, transformers, and transmission lines, is vital to the provision of a dependable supply of electrical power. The failure or incorrect response of a protection system can result in costly damage to equipment as well as lengthy service interruption and can, in the extreme, lead to catastrophic system failure.

In the past, the desired level of reliability of protection systems was achieved with careful system design that incorporated equipment that had undergone extensive laboratory evaluations to verify its suitability for intended applications. However, higher operating stresses on an expanding power system, coupled with the reality of aging equipment, call for new approaches.

New digital schemes are therefore being investigated to develop "smart" protection systems, which could, among other things, detect weaknesses before actual failure occurs. "Smart" systems can be achieved with current computer technology combined with new fibre optic communication links that are inherently immune to electrical interference. This, in turn, provides the potential to increase the intelligence of a system at discrete locations, thereby allowing "smarter" decisions to be made more rapidly.

Specific activities include evaluation of fibre optic interconnections and the development of digital differential protection for transmission lines. These projects contribute toward an overall scheme for power system integrity control that will, over the next several decades, assist in the maintenance of a reliable power system.

Whereas the above serves to address longer-term objectives, a new standardized approach to implementing protective measures was developed at the initiative of, and in cooperation with, the Protection Design Department. The new technique uses an upgraded Programmable Auxiliary Logic Controller (PALC) and semi-customized Application-Specific Integrated Circuit (ASIC) technology to provide a complete relay protection in a single unit that encompasses both the measurement and logic functions. With this approach, standard hardware and adaptable software can serve many relay functions, including a special turbine protection relay based on the monitoring of frequency and negative sequence current. Most of the 100 new PALCS manufactured to date have been committed for installation.

System protection, no matter how effective, cannot compensate for poor component reliability. Special attention is therefore given to the long-term reliability of Gas-Insulated Switchgear (GIS), for voltages up to 500 kV, which must meet stringent performance standards, since

**"Innovative research
can provide the
new technology required
to meet tomorrow's
technical problems"**

Anton Baljet, Manager



even relatively low failure rates may be unacceptable in some locations.

The Research Division, under EPRI sponsorship, and with the support and cooperation of manufacturers, the Technical University of Denmark, and the University of Connecticut, has undertaken a study to gain a fundamental understanding of insulation failure mechanisms, which will lead to a better definition of critical design parameters. An important breakthrough is the development of a vastly improved technique for detecting minute insulation weaknesses that could develop into support insulator failures.

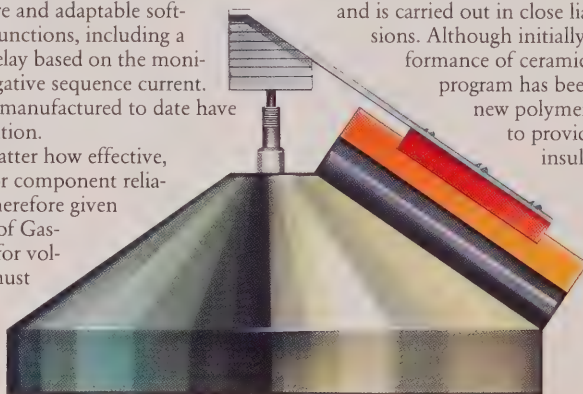
With the emergence of metal-oxide gapless arresters, renewed emphasis on lightning and surge protection has become necessary to secure better performance and to avoid misapplication of future arrester designs. The close cooperation of researchers and manufacturers and their effective participation on national and international technical committees have been essential in working toward the common goal of better over-voltage protection.

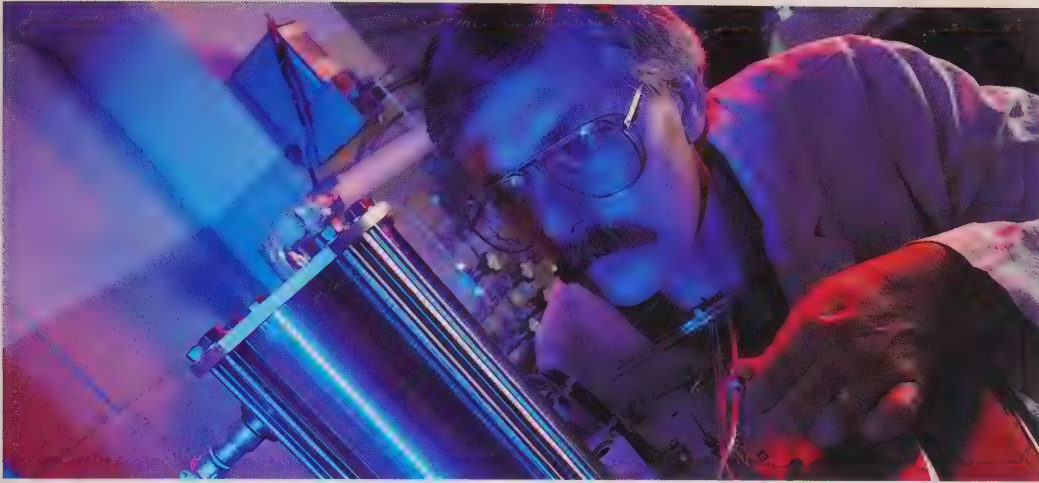
As municipal distribution systems are expanded or upgraded to meet increased load densities, concern for long-term reliability assurance becomes acute. These concerns can be addressed most effectively by extensive distribution system component testing and failure analysis. Components tested include surge arresters, fuses, separable connectors, and underground cables. Technology transfer is accomplished through upgraded purchase specifications and active participation in writing industry standards. As a result, these efforts will benefit not only distribution systems in Ontario, but also utilities throughout North America.

An intensive study of the performance of outdoor high-voltage insulation in adverse winter weather continues. This study involves several technical disciplines

and is carried out in close liaison with other divisions. Although initially addressing the performance of ceramic insulators, the research program has been extended to include new polymer insulator designs and to provide guidance to polymer insulator manufacturers.

As part of the Department's mandate to provide in-house technical support, special high-power electromagnetic techniques were developed





David Bellamy, technologist, Electrical Research Department, is shown operating a low inventory cryogenic distillation column used for tritium separation.

to assist in the assembly and repair of nuclear reactors, the objective being to keep costly downtime to a minimum. Some of these techniques are applicable to energy-efficient industrial processes and, in support of the Corporate objectives, are expected to achieve larger reductions in demand by the year 2000. Whereas substantial reductions can be achieved by simple economic incentives and the application of selected mature technologies, the full potential of economic demand reductions can only be realized if additional benefits are derived from new technologies now under development. With this in mind, the Research Division has implemented a multidisciplinary utilization strategy that relies heavily on liaison with stakeholders and close cooperation with industry. From a corporate viewpoint, this will help ensure that planned demand management investments (i.e., investments in customer-owned equipment to produce power system benefits) will provide the anticipated benefits to Ontario Hydro and the municipal utilities in the province. Past and current industrial support involving electrical processes in manufacturing is wide ranging and includes topics such as electromagnetic aids to steel making, laser welding and cutting, and plasma material processing.

By participating in a 1 000-house survey with Energy Management Branch, Economics Division, and external consultants, the Research Division has helped assess the maximum economic potential for electricity savings in thermal envelope and heating system upgrades in existing dwellings. This evaluation has defined the impact that housing upgrades can have on

the Ontario Hydro system and has provided information for developing demand management programs with realistic targets. Another recent contribution is a newly developed model of energy consumption in single-family dwellings that ensures that utility planners do not overestimate the possible savings from air-sealing and basement re-insulating. Along with this model, better criteria ensure that the upgrades do not adversely affect indoor air quality.

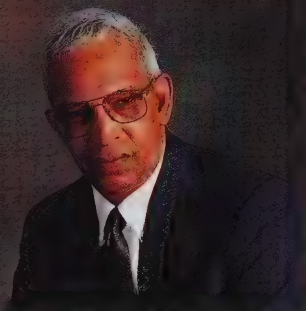
Testing and development work with a Canadian heat pump manufacturer has resulted in the design of an improved hybrid-heating and air-conditioning system that can significantly lower the winter peak demand for electricity in the province. This class of burner-assisted heat pump can potentially save over 100 MW of system peak capacity if installed across Ontario.

Whereas many high-priority research and development activities in the Department are intended to provide a measure of technological assurance for the future, one of the most important considerations in directing a research program of this kind is the ongoing cooperation of many departments across the Corporation. Several of the projects now underway in Electrical Research are the result of initiatives taken elsewhere in Ontario Hydro. Only through the commonly shared objective of "making it happen" can front-line technology meet our high expectations. A well focused and consistent research program with equal emphasis on development and implementation may help to exceed those expectations.



"R&D support ensures the structural integrity and reliability of plant equipment and components"

Gord Clarke, Manager



The operation of Ontario Hydro's generation, transmission, and distribution systems must be reliable, safe, support a sustainable environment, and supply electricity to the customer at reasonable cost. The Mechanical Research Department helped the Corporation respond to this challenge in 1989 by its involvement in a wide spectrum of activities, all of which facilitated the implementation of technologies that helped assure the effective future functioning of Ontario's power system.

Ontario Hydro is concerned about the aging and deterioration of its power system components. Some transmission lines have been in service since 1906. To help ensure their maximum reliability, the Research Division is committed to a transmission line refurbishment program. Initial efforts are to establish that towers do have reserve strength and that modern design methods give adequate strength predictions. Hardware and insulators are to be renewed, and overhead ground wires are systematically being replaced. Other activities related to the planning aspects of transmission refurbishment include developing criteria for prioritizing lines for refurbishment on the basis of useful remaining life. Determination of the preferred sequence of refurbishment will be based on these criteria.

This year, a major activity related to the refurbishment effort was the Department's participation in full-scale field testing of transmission towers. Stresses and deflections were measured to determine available levels of reserve strength. This year, 115-kV double circuit McGuigan-type transmission towers, built in 1911 in Oakville, were subjected to testing under various conditions. The results will be of great value in the assessment of older lines and in the development of an economical and technically sound refurbishment program.

Not only Ontario Hydro's transmission lines are aging, some of Ontario Hydro's generation plant is being refurbished to ensure its continued reliable generation. The Mechanical Research Department is involved in testing hydraulic runners. Results of these tests will contribute to an inventory of information, which will be helpful in the assessment of runner condition, determination of remaining runner life, and the

need for runner repair or replacement. To aid this effort, a test rig has been built for the testing of runners removed from generating plant at the end of their operating lives. Runners are to be tested to destruction by subjecting them to the speeds and accelerations they experience during in-service operation.

Other work being done in the Mechanical Research Department relates to the development of equipment condition monitoring systems. Various types of computer-managed rotating-equipment monitoring systems have been developed, and technical assistance has been provided to a number of plants relating to their implementation. The information generated by these systems allows maintenance to be performed on a timely basis only on those components that need it. Avoidance of unnecessary maintenance and timely diagnosis of components requiring unexpected repair means an increase in equipment reliability and the minimization of plant downtime as well as cost. Already, these systems have been instrumental in detecting loose parts (debris, failed components, tools, etc) that, if not removed, would have resulted in significant damage and equipment downtime. The effectiveness and efficiency of monitoring systems is expected to be enhanced even further by the application of research currently being done in advanced signature analysis, neural networks, and expert systems.

The Mechanical Research Department plays a leading role in coordinating the Research Department's contribution to developing methods to deal with the containment and immobilization of irradiated fuel and safe methods of storage, transportation, and ultimate disposal of high- and low-level nuclear wastes. Currently under development are a tritiated heavy water transportation package, a cask for transporting irradiated fuel, and other specialized containers. Experimental impact tests and extensive finite element analysis have demonstrated the impact resistance of the transportation package. On the strength of this work, a transportation licence has been obtained from the Atomic Energy Control Board.

Study continues on the analysis of hydride blister formation in Canadian Deuterium Uranium (CANDU) reactor pressure tubes. Mathematical models are being developed to predict hydrogen transport and blister growth and to predict the useful life of pressure tubes under a variety of conditions. Another pressure-tube-related study involves the development of a computerized program that can predict the degree of degradation occurring in pressure tubes due to creep. Data generated by this program can then be compared to data obtained through in-reactor measurement. Studies are also being carried out to determine whether or not it is creep deformation that is responsible for allowing pressure tubes and calandria tubes to come into contact. Yet another pressure-tube-related study is attempting to determine the effect of fretting on the performance and useful life of pressure tubes and calandria tubes. The





Tests to study the structural integrity and foundation of transmission towers are being carried out on McGuigan-type towers in Oakville, Ontario, as part of the transmission line refurbishment program.

goal of this particular study is the development of a methodological procedure for predicting long-term fretting behaviour using short-term data. Results will provide the necessary tools for identifying vulnerable tubes and for assessing the possibility of life extension.

The Spacer Locating and Repositioning tooling has been redesigned as a response to high wear rates and high friction coefficients of bearing materials in the current design. At the request of AECL, Mechanical Research evaluated the tribological characteristics of a number of selected materials under simulated operating conditions. A database of wear rates and friction coefficients was produced, and based on it, the materials that best met the SLAR redesign requirements were selected.

There is great economic incentive to operate nuclear power units at the maximum output permissible within the licensed limit of reactor power. Reactor power output is determined from an overall plant heat balance, which, in turn, depends on feedwater flow. Thus the accurate measurement of feedwater is important. To check the calibration of in situ plant instrumentation, a non-intrusive flow meter is used. Through laboratory calibration and field trials, Mechanical Research is contributing to further development and proof of the instrument's efficacy.

Another major initiative that has attracted strong interest and funding support from a consortium of international partners is a recently launched project to monitor primary heat transport pumpsets by vibration and acoustic methods. The scope of the project embraces comprehensive dynamic analysis, baseline testing, and fault-simulation tests on a full-scale pumpset in a laboratory.

The recruitment of women to non-traditional jobs is a Corporate objective.

The Department actively participates in the process. Participation is not only limited to offering on-the-job training via developmental rotations, but also to doing work to make equipment suitable for operation by female staff. As part of a fall protection program, a project is underway to design fall protection equipment for the special needs of women. The work is being done in collaboration with the Faculty of Medicine at the University of Toronto. A prototype, fall-protective device is under development and will be tested based on injury threshold and endurance limits for women when exposed to the types of impacts experienced during the arrest of a fall.

What has been described above is only part of the Mechanical Research Department's contribution towards safeguarding the Corporation's enormous capital investment in equipment, components, and in human resources. The objective of this is to ensure that Ontario Hydro's generation, distribution, and transmission systems are reliable, safe, support a sustainable environment, and supply electricity to the customer at reasonable cost.



METALLURGICAL RESEARCH: MANAGER'S OVERVIEW

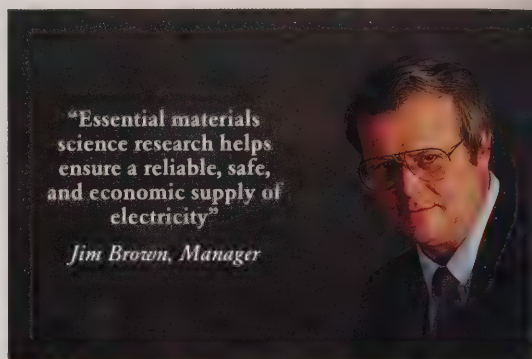
The Metallurgical Research Department provides research and development, technical services, and specialized testing facilities in the disciplines of physical and process metallurgy and materials science. The overall thrust of these activities is to ensure a safe and reliable supply of electrical energy and to improve the efficiency of its utilization. In pursuit of these goals, the Department deals with characteristics of materials' performance and with correlation of both design intent and actual service behaviour.

The majority of the Metallurgical Research Department's work program is focused to support CANDU technology. Analytical and test techniques have been designed to investigate the factors that control the deformation and fracture of zirconium-niobium pressure tubes; it is these that make up the core of a CANDU reactor. An important part of the Department's studies is to achieve end-of-life conditions in tube specimens far in advance of actual in-service components. This is achieved by testing in high-neutron flux reactors, such as in the DIDO reactor in the U.K. Work has been ongoing in this reactor for several years, samples there being close, in terms of total fluence, to material in those Hydro reactors with the longest operating lives. Even better facilities are now available in the OSIRIS reactor in France, where experiments began this year. Resulting data will provide input useful in developing design equations and, additionally, in establishing the effect of irradiation on the microstructure of pressure tube alloys. Transmission electron microscopy studies of irradiated material are being carried out, both in the Department and at the University of Cambridge in the U.K.

Crack nucleation and growth are studied using samples of pressure tube material where hydrogen concentrations have been increased to end-of-life levels; particular emphasis is on the formation and growth of hydride blisters as precursors to crack initiation. A pressure tube burst rig is fully operational and supported by flaw evaluations, which utilize techniques of elastic-plastic fracture mechanics. An additional test rig has been developed to conduct corrosion fatigue tests of zirconium-niobium in primary heat transport water.

Most corrosion-related studies are focused on establishing a detailed understanding of the principal source and ingress route of deuterium into the pressure tubes. This year saw the application of secondary ion mass spectroscopy and transmission electron microscopy to examination of the interface between oxide and metal. The critical nature of the oxide layer as the deuterium-ingress controlling feature, from both the water and annulus gas sides of the pressure tube, was confirmed.

The accurate measurement of hydrogen/deuterium in irradiated pressure tubes has received a great deal of attention this year. A nondestructive evaluation (NDE) technique that uses resistivity changes in materials as a function of hydrogen concentration was successfully demonstrated. Other advances in the NDE area included the development of laser thermography to measure annulus gas flow, a technique that is described in detail in the earlier article, "Safeguarding Corporate Investment: Research and Development as Technological Insurance." Also, new pressure tube scanning software developed in the Department was used in



inspections of Unit 3 of Bruce NGS and Unit 6 of the Pickering NGS. This software permits imaging of defects in such a manner as to allow for better estimates of radial depths.

Progress continued in the area of digital signal processing. Deconvolution techniques were used to improve eddy current gap measurements. Blister crack depth measurements obtained by ultrasonics were optimized by synthetic aperture focusing and filtering. Additionally, filtering, windowing, and normalizing of high frequency spectra were used to measure pressure tube oxide thickness.

Although the Department is heavily committed to fuel channel research, other components of nuclear generating plant are receiving attention. Laboratory data have implicated a microbiological component in the corrosion of lakewater-cooled heat exchangers. This may have important repercussions for many nuclear, thermal, and hydraulic systems. Sampling and testing by means of microbiological techniques is being

supported by advanced surface analysis techniques in an effort to determine the impact of microbiological processes on the corrosion. The expertise developed will be vital in minimizing the impact of zebra mussels on station systems.

In 1989, the Darlington NGS heat transport system leak-before-break project was completed. This included extensive elastic-plastic fracture mechanics calculations, computer code development for fatigue analysis, and fracture toughness testing of pipe welds and elbows.

Many departmental resources are directed of necessity toward assuring the reliability of Ontario Hydro's nuclear plants. However, support is also provided to conventional coal-burning units. Support is focused particularly in the area of life extension. A great deal of effort was put into helping Lakeview TGS manage the consequences of weldment creep cracking on one of its main steam lines. This included the initial emergency failure analysis and a comprehensive follow-up of the failure mode. The Department played a major part in the subsequent assessment of the integrity of all high-energy pipe weldments in the plant.

In August, a field test of the robotic system for hydraulic turbine cavitation repair was carried out. During a week and a half at Hydro Québec's Carillon GS, an impressive demonstration of the system's reliability and capability was achieved.





Andy Heics of Metallurgical Research Department is examining a tritium storage bed designed at the Research Division. These beds will be used at West Germany's Karlsruhe Nuclear Research Centre's Tritium Laboratory for the temporary storage of tritium.

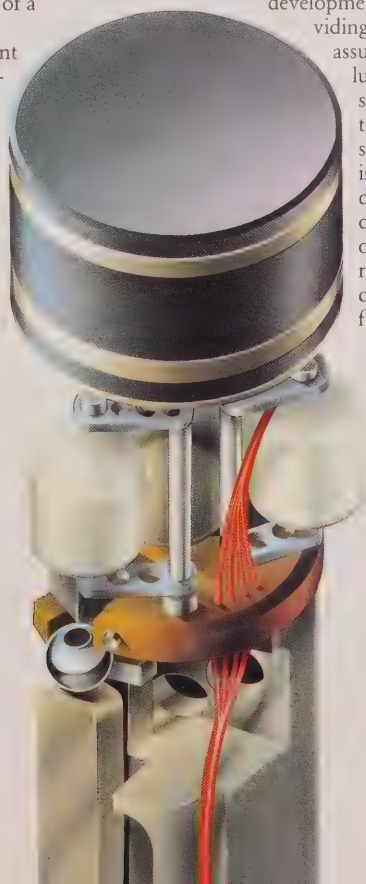
Although the objectives of the CEA-supported development project have now been attained, continued cooperation with the Institut Recherche Electricité de Québec (IREQ) is envisaged to develop the capability further.

In the transmission major program area, the Department, in collaboration with an external commercial laboratory, won a large CEA contract to develop the application of modern fracture mechanics to assure the integrity of transmission line hardware. Effort in this program area is supplemented by a study of the use of advanced materials in the manufacture of a variety of components.

Not all of the work of the Department is directed toward ensuring reliable supply. The tritium laboratory is now almost fully commissioned with multiple work stations and a modified tritium storage and delivery system. A prototype solid, metal-matrix tritium light has been successfully demonstrated. Although, at present, the light is of low intensity, the concept is considered to have a great deal of commercial potential.

Finally, in support of demand management objectives, an electric-arc furnace was built and commissioned. The furnace is to be used to examine ways of increasing the efficiency of the metallurgical and materials processing industry. Metals producers, who are some of Ontario Hydro's most important customers, have shown great interest in the facility, and a cooperative project with Falconbridge Limited is already underway.

The Metallurgical Research Department considers itself to be carrying out a successful research and development program primarily aimed at providing the Corporation with "technological assurance" in the disciplines of metallurgy and materials science. By necessity, the program is focused to ensure the reliability of supply while, at the same time, recognition is given to issues that impact on economic and demand management. Innovations continue to be made in a number of areas with the goal of solving current problems, forestalling future concerns, and providing long-term flexibility.



OPERATIONS RESEARCH: MANAGER'S OVERVIEW

The Operations Research (OR) Department provides applied research and support to the Corporation when unusual and complex operational and strategic problems arise.

Problems run the gamut from those related to management systems and procedures, through those concerning data and information handling, to problems related to equipment and materials. Solving these types of problems requires a full range of state-of-the-art mathematical and computational methodologies.

In 1989, the client base and the range of services continued to expand in the areas of decision and operational analysis, statistical analysis, probabilistic analysis, and power system reliability modelling. Services varied from informal consultations and short presentations to large-scale projects and tailor-made courses and seminars. Specialized computer applications services were provided to Divisional staff. The Department is one of the most active and effective industrial OR groups in North America.

"A concerted team effort enhances management effectiveness and operational efficiency"

Archie Chung, Manager



Although most OR techniques were developed during and after World War II, they are now widely used in business, industry, and government to enhance management effectiveness and operational efficiency.

Traditional techniques such as linear programming, inventory control, and queuing theory have always been important to management studies and, as OR methods have started to merge with information technology, have become essential components of decision support systems. Current interest in the measurement of intangibles and in complex decision processes provides an additional challenge. Problems often involve multiple and conflicting objectives, solutions not being always apparent. Researchers, however, are sensitive to decision environments and able to develop innovative approaches to decision analysis.

After achieving a high degree of diversification over the last few years, this year the departmental team focused its efforts on projects with the potential to contribute to enhancements in strategic planning or operating efficiency. Services were provided to a number of Branches, which included Production, Regions, Finance, and Supply and Services. An example of this effort is the development of a manpower planning model for electrical inspection. This model will be used by all regions in Ontario Hydro and will enable manpower requirements to be determined more accurately. An example

of an efficiency improvement project is the application of optimization techniques to hydraulic generation. The computerized optimization model is expected to improve station operating decision-making and reduce judgemental error, which, in turn, may result in substantial savings.

Since a reliable supply of electrical energy is part of Hydro's mandate, accurate reliability predictions for power systems and their constituent parts is a most important engineering task. Equally critical is the assessment of risk involved in many operating situations. The development of reliability methodology based on probabilistic modelling has come a long way in the last 25 years, but the methodology is still not mature enough for use in all applications. The Department's reliability team, however, is at the forefront of the world-wide effort to develop more advanced reliability tools.

The team's involvement with the development and application of mathematical models for system and component reliability spans almost two decades. The objective has been to assist the Corporation's planning, operating, design, and maintenance functions. In 1989, the reliability team engaged in developmental work and provided technical assistance to other Divisions. Important progress has been made in the optimization of maintenance procedures and the development of new concepts and modelling techniques, which were introduced to represent the processes of deterioration and failure. The reliability evaluation of the control and operating facilities for the new System Control Centre at Clarkson was completed with a report and a presentation to client and users.

Through publications and participation on committees and in conferences, the reliability team's international reputation was enhanced. This year, staff were involved in a number of international technical activities, including participation in a working group at CIGRE. The team continues to be involved in industrial advisory activities for several EPRI research projects, and it has delivered seminars on power system reliability analysis in Canada, the United States, and in Hungary.

The selection and analysis of data for technical or management studies often appear straightforward. However, when data are scarce, interrelated, dispersed, or even contradictory, the drawing of valid conclusions requires advanced statistical analysis. Assistance in solving statistical problems is provided by the statistics team. The team's expertise includes knowledge of sampling schemes, statistical estimation, experimental design, forecasting, regression analysis, probability theory, mathematical modelling, quality control, and quality assurance.

In 1989, the team performed a number of studies for other Divisions as well as for the Research Division. Studies included the development of a forecasting method for the Niagara River flows; the development of techniques capable of detecting temporal shifts in climate at the regional level due to the Greenhouse

effect; the estimation, from the observed temperature profile, of the rate of gas flow through the annuli around pressure tubes; and the determination of the impact of converting M&P salary ratings to Hay system ratings. In addition, members of the team participated in the working party on the environmental and





Dennis Gousbleff of Operations Research Department discusses with Harry Mewes of Supply Division how a recently developed forecasting model can be used to set reorder points for materials in the stores inventory.

safety research assessment of the CANDU Owners Group Waste Management Program. Assisting clients through informal consultations continues to be an important part of the team's activities.

In recent years, rapid advancement in computer technology has provided the computer support team with new challenges. In 1989, apart from the internal specialized service function, emphasis was placed on the adaptation of new computer technology to solve engineering and scientific problems. Examples are the development of an environmental database, signal processing, and computer communication.

The advancement in computer and information technology has created opportunities of strategic importance to Ontario Hydro's effective and efficient operation. Among them are artificial intelligence and database technology. In 1989, the Department was engaged in the successful development of prototype expert systems. Identification of high payback opportunities continues. Work is being done on estimating the errors associated with computer vision, which at this time is limited. The work will be important in the robotics area. Neural network technology continues to expand the pattern recognition capability of computer systems. With rapid developments in these fields, special applications in robotics, pattern recognition, and knowledge preservation and distribution are anticipated in the near future.

The Department continues to be involved in external

activities with universities, professional associations, and research institutes. A number of staff members held adjunct professorships or served as executives or committee members with professional societies or research granting agencies. Informal collaborative research arrangements were made with universities. Internships were offered to the University of Strathclyde in Scotland. Staff were also invited to make technical presentations at various universities and to industries world-wide.



RESOURCES AND COSTS

At the end of 1989, the Division's personnel resources consisted of a total regular staff of 633. The percentages of funds allocated to major work programs and the percentages of program costs attributable to OM&A – the net cost to Ontario Hydro to operate, maintain, and administer the Research Division – are shown below. Also shown are the application of staff in various categories of work (Divisional Services Department excepted), and the distribution of staff in broad occupational classes.

The total of all costs, including those for space, materials, and equipment, for work done by the Research Division in 1989 was approximately \$74.2 million.

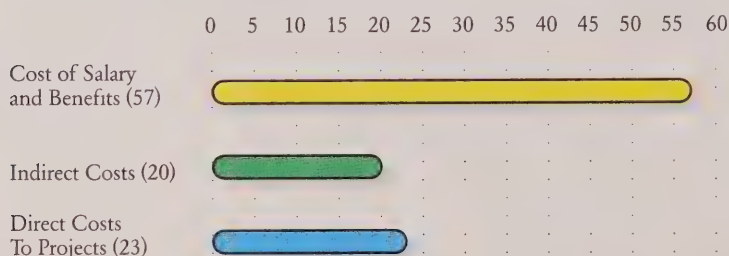
Costs were met or allocated as follows:

Revenue from work done for other organizations	3.9 M
Transfers to other Ontario Hydro Branches	36.8 M
Transfers to the Cost of Power	33.5 M

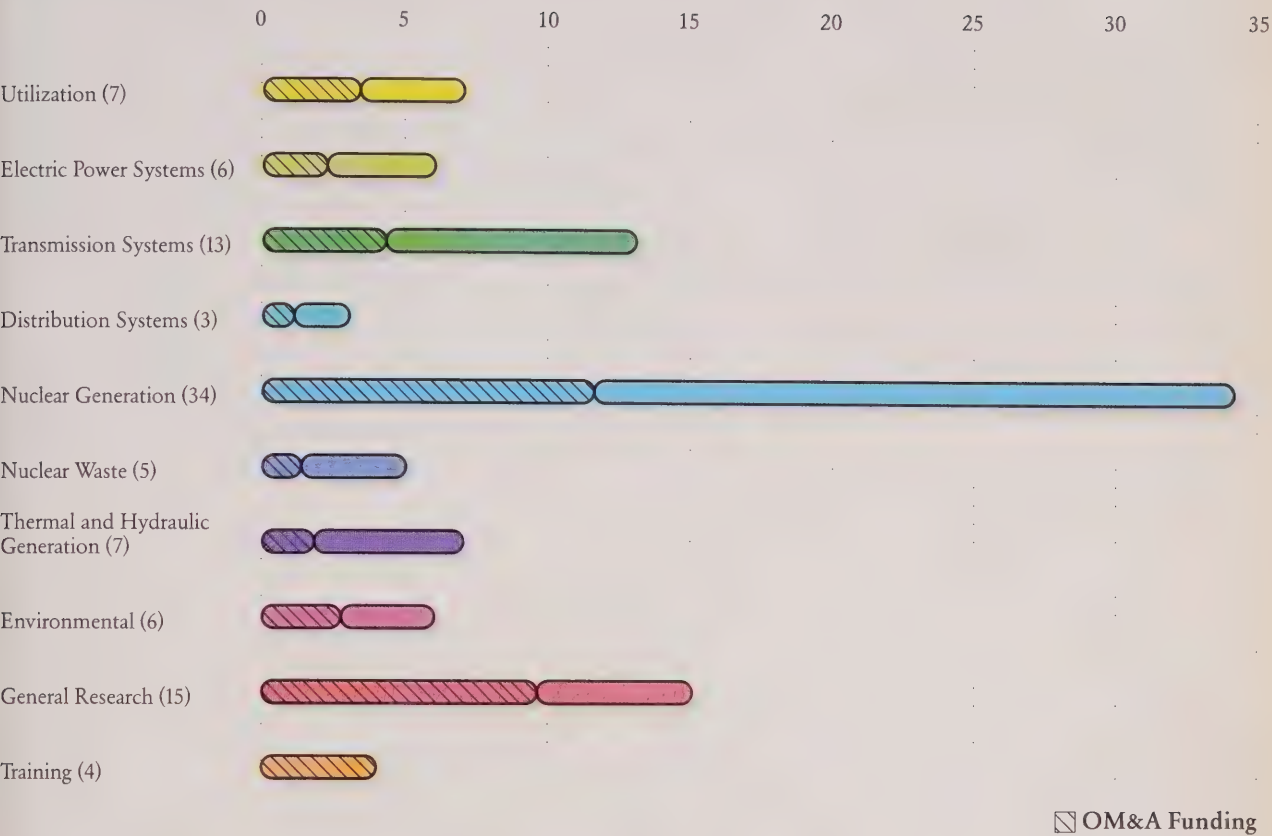
Proportions of Research Division Costs for Various Categories of Work



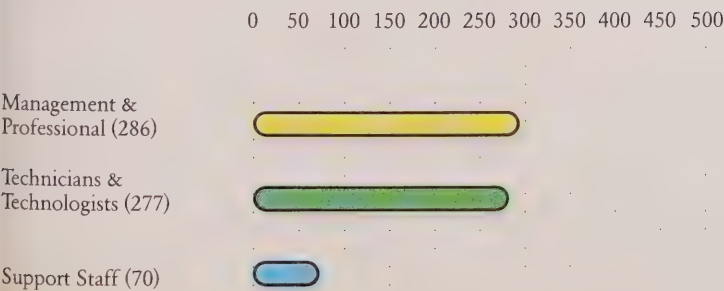
Research Cost Breakdown by Major Resource Categories (% of Gross Costs)



**Research Division Programs:
Proportions by Actual Gross Costs for 1989**



**Occupational Classification of
Research Division Staff**



AWARDS AND ACHIEVEMENTS

"A Discharge-Locating Probe for Rotating Machines," a research paper co-authored by Howard Sedding and Greg Stone (Electrical Research), was chosen from among 117 others presented at the Chicago '89 Electrical Electronics Insulation Conference/International Coil Winding Association Exposition to be awarded the \$1,000 grand prize. The probe described in the paper was developed by OHRD, and through the use of a capacitive sensor that can detect radio frequency stator emissions, it solves the problem of partial discharge location.

Hugh Morrison (Electrical Research) has been awarded a prestigious research fellowship from the Science and Technology Agency of Japan to work in the national laboratory, the Institute of Physical and Chemical Research (RIKEN). The Hydro researcher, who in January 1990 began working on laser isotope separation with Kazuo Takeuchi of the Laser Science Group, was one of only five candidates selected from Canada for the fellowship.

For the first time in its history, the American Society of Mechanical Engineers (ASME) has presented the ASME Blackall Award to a Canadian team. Helmi Attia (Mechanical Research) is this year's recipient for leading-edge research on nonlinear thermoelastic behaviour of structural joints, a research project that extended over 10 years and resulted in the publication of more than 15 papers in refereed journals.

Steve Oda (Electrical Research) was appointed to the Board of Directors of the Industrial, Scientific, Medical, and Instrumentation (ISMI) Section of the International Microwave Power Institute (IMPI), which is headquartered in the United States. Steve Oda's appointment is the result of Utilization Section's involvement with the application of microwaves for industrial material processing, particularly in the area of ceramics.

The quality of publications produced in the Divisional Projects Department continues to attract the attention of the Society for Technical Communications (STC). This year the Services and Capabilities brochure won the prestigious Distinguished Award, the 1989 Research Annual and Chit Chat won awards of excellence for writing and design, and the series of bookmarks, "Hydrolines" was also recognized by an Award of Achievement. The STC is the world's largest professional organization devoted to the arts and sciences of technical communication.

Scott Lawson (Metallurgical Research) was awarded the Welding Institute of Canada's annual Robert J. Jacobson Memorial Award for his contribution to the operation of a local Chapter. Scott Lawson was an executive member of the Toronto Chapter of the Welding Institute from 1978 to 1988. Additionally, he served as Chapter chairman during the years 1980 and 1981.

For the fourth consecutive year, Holly Anderson (Mechanical Research) has been appointed to the national executive of Women in Science and Engineering/la Corporation des Femmes en Sciences et en Génie (WISE/CFSG), this year as national co-director. The nonprofit organization encourages women to enter careers in science, engineering, mathematics, and computer sciences by providing speakers for career

guidance sessions at local schools and by organizing conferences for female students. WISE/CFSG also serves as an information centre for and about women in these professional fields, thereby helping Canadian women to attain high levels of professional achievement.

Early in 1990, PRECARN Associates Inc. will embark on a \$28 million research program. In anticipation thereof, its Board of Directors approved four recently completed feasibility studies, one of which was submitted by the Research Division. Bruce Nickerson (Electrical Research) was the lead applicant for funding of a project that concerns active vision navigation of a mobile robot in a known environment. Federal government and private sector financial assistance are also expected to be confirmed for this project.

Soon-Hok Sim (Operations Research) has been appointed as a member of the Industrial Engineering Chairman's Advisory Board at the University of Toronto. The appointment involves assisting the Department of Industrial Engineering to maximize the quality of its curriculum, increasing the amount of research and development work conducted by the department, and promoting and increasing employment opportunities for the department's graduates and undergraduates.

Staff at OHRD have, over the past two years, organized the Canadian Industrial Laser Association (CILA), which acts as a national body to (1) provide an unbiased source of laser technology information and (2) bring together new and experienced laser users. The development of this association will increase acceptance of laser technology and contribute to the Research Division's effort to transfer energy efficient electro-technologies to Canadian industry. The inaugural meeting of CILA was held in March 1989 under the chairmanship of Jim O'Neill (Electrical Research), and was attended by approximately 100 people representing government, industry, and academia.

Nineteen eighty-nine marked the first year that Ontario Hydro President and CEO Robert Franklin recognized the development of new technology for Hydro in the form of the first annual New Technology Awards. John Deans and Joseph Vitanyi (Civil Research), along with Joseph Phillips of Transmission Programs Group, shared a \$10,000 New Technology Award for solving the problem of winter-time transmission line construction and repair. The newly developed very low-temperature polymer concrete can be placed without the need for costly and time-consuming heating and housing during the curing process. The concrete technology is expected to save the construction industry tens of millions of dollars.

The Stable Isotope Research (SIR) program is a five-year joint effort between Ontario Hydro's Research and New Business Ventures Divisions. Created to develop and bring to market new isotope technologies, materials, and applications, the SIR program is especially interested in collaborating with business, industry, and academic researchers to meet its objectives. Dennis Mullins (Chemical Research) and Jeffrey Robins (Electrical Research) are co-organizing work in the Research Division that currently focuses on the stable isotopes of hydrogen, carbon, oxygen, and nitrogen.



From left to right: Robert Franklin, President and CEO of Ontario Hydro; John Deans, Joe Phillips, and Joe Vitanyi, prize-winners; and Ray Brown, Director of Design and Development – Transmission. Prize winners received a shared \$10,000 award for their role in the development of a polymer-based concrete that properly cures at temperatures as low as -25°C .

The 1988 Research Division W.P. Dobson Award was presented to John Janis (Chemical Research) for his development of a PCB dechlorination process. His technology was approved by the government in 1987 and is currently utilized by private industry throughout Ontario, Quebec, and the Maritime provinces.

Since 1985, the H.A. Smith Award has been offered for outstanding contributions that have had a major impact on the business of the Research Division. Nineteen eighty-eight recipient Andrew Sulowski (Mechanical Research), recognized for his research in the field of fall protection, has earned an international reputation for his extensive, leading-edge work. His new fall arresting system has prevented at least four potentially fatal accidents, and there has been no fatality attributable to a fall since his system was implemented in 1984.

Steve Campbell (Electrical Research) earned a 1988 Research Division Director's Award for technical competence and service above and beyond the call. Steve Campbell developed a breakthrough technology for extracting diagnostic signals from operating turbogenerators.

Craig Simpson (Divisional Projects) was recognized with a 1988 Research Division Director's Award for his role in the research and development of new industrial electrotechnologies. His efforts were invaluable in the establishment of both the Process Metallurgy Group and the Lakeview Plasma Facility.

Carolyn Ashby and Chuck Blacklock (Divisional Services) were recognized with a 1988 Research Division Director's Award for their creation of an innovative mural in the Nondestructive Evaluation Laboratory. The mural, which enlivens the laboratory workspace, has been such an overwhelming success that similar projects are planned in the Division.

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ACRONYMS

AECB	Atomic Energy Control Board	OCMR	Ontario Centre for Materials Research
AECL	Atomic Energy of Canada Limited	OHRD	Ontario Hydro Research Division
ASIC	Application Specific Integrated Circuit	OR	Operations Research
ASME	American Society of Mechanical Engineers	PALC	Programmable Auxiliary Logic Controller
CANDECON	CANDU Decontamination	R&D	Research and Development
CANDU	Canadian Deuterium Uranium (reactor)	RIKEN	Institute of Physical and Chemical Research
CEA	Canadian Electrical Association	SIR	Stable Isotope Research
CFFTP	Canadian Fusion Fuel Technology Program	SLAR	Spacer Location and Repositioning
CIGAR	Channel Inspection and Gauging Apparatus for Reactors	SRB	Sulphate-Reducing Bacteria
CIGRE	International Conference on Large Electrical Systems	STC	Society for Technical Communication
CILA	Canadian Industrial Laser Association	TGS	Thermal Generating Station
COG	CANDU Owners Group	URL	Underground Research Laboratory
CPSD	Central Production Services Division	WHMIS	Workplace Hazardous Materials Information System
CUICAC	Canadian University – Industry Council for Advanced Ceramics	WISE/CFSG	Women in Science and Engineering/ la Corporation des Femmes en Sciences et en Génie
EPRI	Electrical Power Research Institute		
GEMS	Generator Expert Monitoring System		
GIS	Gas-Insulated Switchgear		
GS	Generating Station		
ICE	Integrated Computing Environment		
IEEE	Institute of Electrical and Electronics Engineers (USA)		
IMPI	International Microwave Power Institute		
IREQ	Institut Recherche Electricité de Québec		
ISMI	Industrial, Scientific, Medical, and Instrumentation (Section)		
MSDSs	Material Safety Data Sheets		
NDE	Nondestructive Evaluation		
NGS	Nuclear Generating Station		
NPD	Nuclear Power Demonstration (unit)		
NPLA	Nuclear Plant Life Assurance		
NSERC	Natural Sciences and Engineering Research Council		

SIGNIFICANT RESEARCH CONTRIBUTION

ANNULUS GAS CARBON-14 REMOVAL SYSTEM AND OXYGEN ADDITION SYSTEM

From left to right:
Chris Cheh,
Frank Greening, and
Ron Massey.
Chris Cheh holds a
sample of commercially available
calcium oxide, which
is used to prepare the
calcium hydroxide
essential to the
carbon-14 removal
process.



In CANDU reactors, carbon-14 (^{14}C) is produced primarily in the moderator cover gas system and in the nitrogen annulus gas system. Carbon-14 has been identified as a potential health hazard, attributable to both the ease with which it may be assimilated into the biosphere and its long half-life of 5730 years. Without a removal process, gaseous ^{14}C is eventually released into the environment during pressure relief venting and purging operations. In anticipation of regulations requiring further reduction in ^{14}C emissions, a research and development ^{14}C control and removal program was initiated by the Chemical Research Department over a decade ago.

Prior to the research effort at OHRD, three methods of removing carbon dioxide from gas existed, all of which were disadvantageous or hazardous. In the course of their research, Chris Cheh and Roger Glass discovered that the solid calcium hydroxide system for removing carbon dioxide from gas, previously considered undesirable because it necessitated operation at temperatures approaching 450°C , was effective even at ambient temperatures if the humidity of the gas were raised. This solution to the high-temperature problem constituted an initial breakthrough that led to a series of other findings, ultimately ending in 1989 with the installation of the Annulus Gas Carbon-14 Removal System and Oxygen Addition System at Pickering NGS Units 3 and 4.

The ambient temperature process, which uses calcium hydroxide as the sorbent to remove radioactive carbon dioxide ($^{14}\text{CO}_2$) from gaseous streams, is a safe, simple, and reliable method. It was first tested in actual plant conditions at the Nuclear Power Demonstration (NPD) unit. The ^{14}C removal system used in the moderator cover gas system at NPD was designed and built at

Research Division by Shinn-Der Chang, Chris Cheh, and Rick Currie. It operated for approximately 600 hours before its return to OHRD upon the shutdown of NPD.

After an in-house evaluation of the NPD system, the research team concluded that, with only minor modifications, the system could be used to solve another ^{14}C problem that had surfaced at Pickering: Decontamination of the annulus gas system took on unprecedented importance in 1985 when, during major retubing operations in Units 1 and 2, work was impeded by the unexpected finding of contamination from ^{14}C in the form of an easily dispersed fine black dust. Chris Cheh and Pat Marchione undertook to adapt the system to meet the new needs of Pickering's annulus gas system.

The investigative work of Frank Greening on the nature of the ^{14}C deposit in Pickering Units 1 and 2 directly influenced the decision to add oxygen to the annulus gas system to oxidize ^{14}C to $^{14}\text{CO}_2$. Addition of oxygen facilitates the removal of ^{14}C , with a concomitant benefit of the process being the maintenance of a protective oxide layer on the pressure tubes. Monitoring of the progress of the oxidation and ^{14}C removal was carried out by Analytical Services staff, namely Ron Massey, Ivan Hunter, Peter Agg, Don Oberding, and Wojciech Schmidt.

On July 26, 1989, the Annulus Gas Carbon-14 Removal System and Oxygen Addition System at Pickering Unit 4 were declared in service. Similar systems at Unit 3 had been operating for months. The successful implementation of this technology marked the culmination of many years' research and development and has earned the members of the Chemical Research team deserved recognition throughout the Corporation.

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Research

Cover Photo

Surface science techniques have applications central to ensuring the reliability of Ontario Hydro's generating plants and also fundamental value to studies of corrosion-inducing mechanisms. Here, prior to examination by Auger spectroscopy, a metal foil is being inspected visually for surface defects.

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Vice President's Message

One of the challenges faced by all innovators is that of getting their ideas implemented and their products used. This process, technology transfer, is crucial to innovation. The Research Division is no exception, and the transfer of technology both internally and externally is an important part of its mandate. This process has been ongoing for over 75 years, and the innovations produced by the Division have helped make Ontario Hydro a world leader in the electric power industry.

By facilitating the transfer of technology to industry, both that developed by Hydro and by others, the Research Division helps Ontario's manufacturers use energy, particularly electricity, more effectively. The Division's assistance given to one Ontario manufacturing company helped to improve the efficiency of its heat pump products, thereby improving competitiveness and providing the potential to reduce electrical demand in the province. In another instance, an innovation in continuous casting technology currently being transferred to a local steel producer will potentially result in large electrical energy savings, thus providing benefits both to the producer and Ontario Hydro.

Other avenues for technology transfer are being used. Representatives of industry ask the Division's experts to participate in manufacturing consortia and to support new products that incorporate innovations produced by the Division. New Business Ventures Division actively markets the Research Division's products. Technology transferred to industry in this way helps Ontario industry and returns some of the money invested in research to the Corporation. New Business Ventures Division is also participating in a new venture, IRIS Power Engineering. This company, founded by former Research employees, will utilize technology developed by the Division to its own benefit and that of Ontario Hydro.

Over the past eight decades, Ontario industry and the Province have benefited from technology developed by, and transferred from, Ontario Hydro research activities. I anticipate that Hydro's contribution to our Province will continue, with emphasis on helping our customers make effective and efficient use of electricity by applying appropriate technologies to meet their needs.



A.R. Holt
Vice President
Corporate Planning



Colin Campbell (Vice President, Operating Services, Dofasco), Al Holt, Frank Pickard (President and CEO, Falconbridge), and Gordon Thursfield (Vice President, Energy Group, Canada Wire and Cable) discuss the value of more efficient electricity use to Ontario industry.

Director's Message

In 1990, the Research Division successfully met the many demands presented by Ontario's power system. Success was directly attributable to the highly trained and dedicated researchers hired by the Research Division in the past. But what of the future? Will we be able to maintain our record of research excellence into the twenty-first century?

Like the rest of Canadian industry, we require a continuing supply of bright researchers to supply the knowledge and new ideas necessary to provide the innovations we need to remain competitive. Since the late 1960s, science and technology in the Western world have fallen from favour. The emphasis of business and education has shifted away from the creation of wealth to focus on its manipulation. As a result, projections indicate that the supply of qualified researchers will be inadequate to meet the needs of Canadian industry over the next decade.



Ensuring the life of older facilities demands the cooperation of both technical professionals and management. Here, Jim Sato (engineer), Bob Lococo (mechanical maintenance foreman), and Don Mills discuss the refurbishment plans for the Ontario Power Generating Station at Niagara Falls.

While the education system is the foundation of a vigorous science and technology base, it cannot do the job alone. Science and engineering must compete more effectively as career choices for young people. Thus, there must be evidence that these disciplines will provide meaningful and financially rewarding careers. The Research Division plays an important role in the education system. Our researchers give presentations in local schools on careers in science and technology and provide support for other science education activities. Arrangements are made for promising science and engineering students to visit our laboratories. We provide work opportunities for students, both during the summer and during the academic year. Some of our researchers hold adjunct professorships at Ontario universities and participate in the National Sciences and Engineering Research Council (NSERC) industrial postdoctoral program by providing recent graduate scientists opportunities to work in their fields in an industrial setting.

In addition to encouraging students to choose careers in science, the Research Division also provides career opportunities in a number of technical areas as evidenced by the contents of this annual. The Division has taken a leadership role in developing dual career paths in order to provide technical professionals with the same rewards as employees interested in management activities. Continuing job training, challenging work, and opportunities for peer interactions contribute to an exciting environment for rewarding careers in science and engineering.

The opportunities and work environment afforded by Ontario Hydro's Research Division have enabled us to attract and keep a highly qualified staff. Our excellent staff in turn has allowed us to successfully deal with the challenges presented by the power system over the years. I would like to thank the Managers of the Research Division and their staff for contributing to this enviable record in 1990.

A handwritten signature in dark ink, appearing to read 'D. Mills'.

D. Mills
Director
Research Division

Excellence, innovation, internationally acclaimed research, and timely commercial implementation allow the best of technology to be turned to Corporate advantage.

Ontario Hydro's central mandate is to provide safe, reliable, and economical electric power to the province of Ontario with due regard for sustaining the natural environment. The utility can also make a substantial contribution to provincial economic development through exploitation of the utility's investment in research and development (R&D). New technologies can do more than provide the solution to specific utility problems; they can also help make Ontario industry a serious contender in today's complex, dynamic, technologically oriented global marketplace.

Until 10 years ago, the Research Division saw its objective as solely the support of Corporate needs. This view has evolved into one that recognizes a secondary objective, that of supporting provincial economic development, especially the electrical needs of Ontario industry. Broadly, the Research Division can serve Ontario by

1. Developing new technologies to increase the efficiency of electrical power utilization;
2. Assisting Ontario industry to exploit new, efficient electrotechnologies;
3. Testing industrial products and services that use or rely on electricity;
4. Developing new products that can be licensed or given to industry for sale to other clients; and
5. Performing contract research for companies in areas where Hydro can provide special expertise and facilities.

Any Ontario Hydro strategy for promoting economic development must first ensure that the electric power it produces be used to its very best advantage. Customer needs must be balanced with available electricity resources. In striving to match the supply and consumption of electricity in Ontario, any effort to improve utilization efficiency can be considered an "efficiency resource" that ranks as high as any other on the supply side of the equation. More efficient

electrical utilization is expected to provide the Corporation with the equivalent of a 3 500 MW peak demand savings by the turn of the century.

In support of the Corporate energy management program, the Division seeks to increase the penetration of existing technologies into the marketplace and to aggressively explore the potential of new technologies for future application and development. When in the customer's best interest, the Division helps the Corporation provide customers with the assurance that adoption of an unfamiliar technology will pay off, and with minimum risk to the environment. The Division's extensive research into new heat pump and microwave technology is a prime example of this mandate in action.

Ontario has a climate marked by extremes: its residents cope with extreme winter cold and with considerable summer heat and humidity. Meeting demands for space heating and cooling represents one of the largest energy uses in our climate. Half a million Ontario homes are electrically heated. Collectively, these homes use over 3 000 MW of Ontario's peak load.

Advanced heat pump technologies have been identified by the Research Division as having considerable potential to reduce residential demand. Generally, heat pumps have been developed for climates less severe than ours; however, Ontario's cold winters demand a heat pump with much better winter performance characteristics. This means that Corporate demand management targets can be well served by developing the technology base itself.



Several types of heat pumps can lower the demand for the energy that Hydro produces. A moderate penetration of cold climate air source heat pumps, burner-assisted heat pumps, and ground source heat pumps into the Ontario market could yield at least 300 MW of demand reduction by the year 2000.

A new type of ground source heat pump promises the customer lower capital costs and better performance. Ground source heat pumps use heat present in the earth that has been warmed by the sun and internal sources. Market penetration of this newly available and environmentally friendly technology is being enhanced by a Researchl Division development that obviates the need for a secondary heat exchange step in its operation. Current systems collect heat from the earth through a buried pipe filled with antifreeze. A heat exchange step is required to transfer the collected heat from the antifreeze to the heat pump itself. The refined model extracts heat directly from the ground via a buried copper refrigerant coil. Direct expansion of refrigerant means that heat from the ground is transferred directly to the pump.

Earth energy systems, such as the ground source heat pump, reduce energy costs for heating and cooling. Customers can save as much as 60 percent on their heating costs and 20 percent on air-conditioning.

In today's technologically-driven world, it is not an exaggeration to say that a new technology must make history quickly, or be consigned to it.

Elimination of the heat exchange step translates to a 20 percent savings in the purchase and installation costs of this new version of the ground source heat pump.

Operating costs lower than those of other commercially available heating systems are another advantage. If the operating costs of some popular systems are compared on an annual basis, a homeowner who spends \$1 100 on electric resistance heating could expect to spend about the same on oil heating, and \$600 on gas heating. This compares with only \$400 on the new heat pump system.

Quite apart from the demands of the residential market, industry's needs and expectations for power are growing even as Ontario Hydro's ability to meet those needs diminishes. As Hydro becomes more and more pressed to meet increasing demand and as conventional conservation measures approach the saturation point, further relief can only come from new approaches and new technologies.

Optimizing the spin-off potential of technological advances can give Ontario a competitive edge in the global marketplace. For the Corporation to exploit this potential, the Research Division must ensure the shortest possible time lag between laboratory discovery and safe and economic implementation in the marketplace. In today's competitive world, it is not an exaggeration to say that a new technology must make history quickly, or be consigned to it.

Ontario's steel producers expect substantial cost savings and increased productivity from the development of a new process for the continuous casting of high-grade steel bar products. The concept on which the process is based is simple. A new technological base has allowed the development of a novel radially pulsating mould, which not only produces a better quality surface and internal steel structure, but also integrates the overall casting process.

The Research Division provided research support for the project in collaboration with two major Ontario steel product producers. Funding was provided by Ontario Hydro's Energy Management Branch.

The new continuous casting technology overcomes sticking problems associated with the use of a stationary mould. High-frequency radial pulsation of the mould used in the new, more energy-efficient process results in a marked reduction of friction and, consequently, allows high-speed smooth withdrawal. The result is a cast that is virtually defect free and suitable for further continuous processing.

Ontario Hydro must consider the supply side of the equation as well as the demand side. The utility delivers the power it produces through an electricity grid consisting of integrated 500-kV, 230-kV, and 115-kV transmission networks and extensive distribution systems operating at lower voltages. The delivery system is designed and built to allow Hydro to manage the fluctuations in power flow across the province, including rapidly changing power flow patterns arising from faults, emergencies, and other unusual conditions. Interconnections with neighbouring utilities provide backup to further ensure reliable power delivery. Reliable protection of the components of a system of this complexity is vital. This is especially true of a power system already stressed by high operating demands coupled with the reality of aging equipment.

Within this context, the development of new technologies is particularly important; only through their development can power system growth requirements be met. This is why a substantial portion of Research Division effort is being expended to secure and protect the system and to develop a better understanding of aging mechanisms.



At times, Ontario's winter weather makes ensuring secure power delivery difficult. Insulator flashovers can occur when freezing rain and fog are followed by slowly rising temperatures. On average, the Southern Ontario system might expect this mix of conditions to cause flashover problems every 2 years, but in March 1986, conditions were particularly severe, and a total of 57 flashovers of line suspension and post insulators forced a large part of the 500-kV system out of service. Since that time, a major research program has been underway to gain a better understanding of the phenomena and to develop suitable insulator retrofits for use in vulnerable locations.

The first step was to simulate in the laboratory as closely as possible the specific mix of weather conditions that triggered the events of 1986. The Division's high-voltage laboratory facilities were modified to enable reproduction and control of the variety of factors known to contribute to the flashover mechanism. The combination of factors found to play a key role in producing flashovers were the levels of pollutants on the insulator surface, the rate and amount at which ice formed, and the conditions associated with subzero fog and slowly rising temperatures.

Ontario's steel producers expect substantial cost savings and increased productivity from the development of a new process for the continuous casting of high grade steel.

In the final analysis, it is only operating experience itself that can establish the success of a new technology.

In addition to determining the exact relationship between specific external factors and the flashover event, a complementary research effort resulted in the design of an alternative insulator that exhibits a 20 percent performance improvement over the standard insulator. Polymer insulators are also being evaluated as a means of obtaining better performance at lower cost.

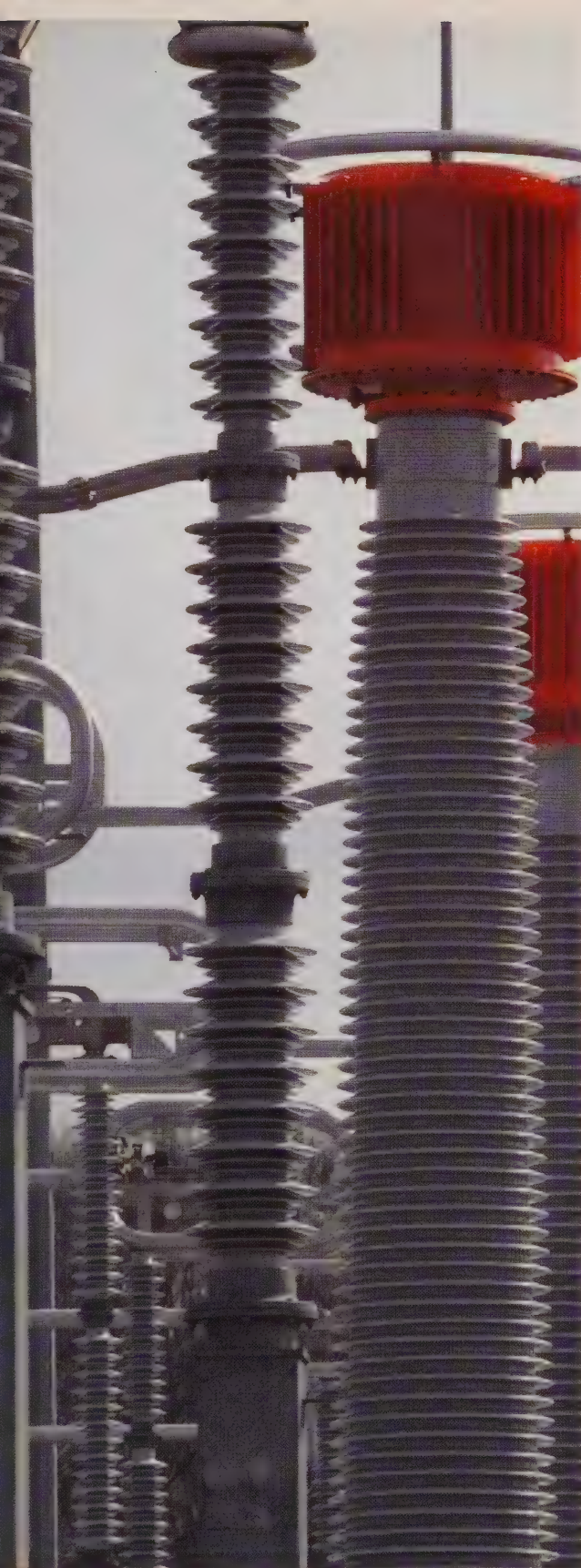
Since the work on outdoor insulators began in 1986, knowledge of weather factors and better simulations have come about as the high-voltage test facility has been upgraded. The big payoff will be improved insulators for stations and lines less vulnerable to flashover under the influence of weather conditions typical of Southern Ontario. For the Division, this means an opportunity to pursue the development of new standards for outdoor insulation; for industry these standards will ensure a better product line of insulators; and for the Corporation a more secure and reliable transmission system. Ontario Hydro leads the world in this area of R&D: no other test facility has the capability of that now in operation at the Research Division.

The work on outdoor insulators has involved the close cooperation of a number of stakeholders elsewhere in Ontario Hydro, which includes System Planning, Design and Development-Transmission; and Power System Operations Divisions. External contracts were also awarded for tasks such as remodelling the fog chamber and for testing the insulators under different conditions. The work on polymeric insulators also involved liaisons with several external organizations, including the Institute of Electrical and Electronics Engineers (IEEE) and the Electric Power Research Institute (EPRI). The work was funded jointly by Ontario Hydro and the Canadian Electrical Association (CEA).

To solve certain transmission line outage problems, new materials that better withstand extremes of temperature and mechanical forces seem to hold much promise. The answer to many types of equipment failure may lie in the development and application of "advanced" materials, which are primarily composites of metals, ceramics, and polymers. The result may be a major opportunity to reduce outages through use of components that possess significantly higher mechanical and environmental stability than those fashioned from traditional materials. As well, transmission line performance will be improved by reducing audible noise, electromagnetic interference, energy losses, and construction costs.

Whereas outdoor insulation reliability is most often a concern of utilities operating in northern climates, the performance of enclosed high-voltage insulation systems concerns major utilities everywhere. As a result, promising insulation techniques are being developed for use in power equipment and underground cables. However, manufacturers and utilities have moved cautiously. In the final analysis, it is only operating experience itself that can establish the success of a new technology.

To reduce the risk of unexpected operating problems associated with the introduction of new enclosed insulation systems, Ontario Hydro has maintained an ongoing research program to assess the performance of SF₆ gas-insulated switchgear (GIS) over a period of 15 years. The Research Division has worked successfully with several other Ontario Hydro divisions, a number of utilities in the United States and overseas, universities in Europe and Scandinavia, and manufacturers worldwide to improve the reliability of both existing and future installations. A recent success story concerns the development of an x-ray induced partial discharge (XIPD) technique that allows the study of the long-term aging behaviour of epoxy-based materials when used as insulators.



The XIPD technique significantly improves defect detection in high-voltage insulating materials as well as the long-term reliability of GIS. Given the critical role that switchgear plays in the transmission system, this technique was badly needed. The XIPD technique is expected to provide the basis for a standard industry acceptance test.

Special attention is currently being given to ensuring the long-term reliability of GIS installations. Newly developed diagnostic tests allow early detection of problems that could lead to failure. Early detection of system deterioration allows time for planned rather than forced maintenance. Another concern of researchers is the provision of safe GIS maintenance procedures.

Problems being experienced by Ontario Hydro relating to GIS technology are common to other utilities. In this sense, the Division's activities will benefit the entire GIS user community, especially since Ontario Hydro has the expertise to influence the writing of industry standards.

The tiered weathersheds of new 500-kV station post insulators designed at Ontario Hydro are expected to improve transmission system reliability during winter fog and freezing rain storms.

Nondestructive evaluation of CANDU reactor fuel channel components provides vital information about the performance and life expectancy of critical nuclear plant components.

Yet another Research Division project is aimed at the early detection of potential reliability problems and at facilitating maintenance to preempt machinery breakdown. The ability to assess insulation quality is essential if Hydro is to purchase wisely, to prevent in-service failures, and to make decisions about refurbishment or life extension of large components. Specific diagnostic instrumentation related to generator insulation has been developed. To date, this technology includes two partial discharge tests that can evaluate the condition of stator insulation in operating turbine and hydraulic generators and a voltage endurance test that accelerates aging mechanisms. The endurance test evaluates the ability of insulation to stand up to the stress of operation at high voltage and elevated temperatures. This test has become an IEEE standard, and the partial discharge tests have been commercialized. Both will be used by utilities the world over. In-service winding failures at Hydro are now virtually a thing of the past.

Like other types of power plants, nuclear stations are susceptible to aging. Even the aging of Darlington, not yet fully in service, must be taken seriously because, when this station is on line, nuclear power will account for 60 percent of Ontario Hydro's total energy production. Addressing uncertainties about age-related degradation of many nuclear plant components—there are thousands—is very different from addressing the same uncertainties about transmission and delivery system components. The problem is often one of access. Manual inspection of the components that make up the core of an in-service CANDU reactor is, of course, impossible.

Inspection of CANDU reactor fuel channel components can be best achieved through their nondestructive evaluation (NDE). NDE technologies are complementary to technologies related to the discipline of fracture mechanics.

Whereas fracture mechanics seeks to predict the performance of materials, components, and structures through both analysis and experiments, NDE enhances this technology by the timely discovery of imperfections that may lead to a structure's early failure. Both disciplines meld together to provide information about the performance and life expectancy of critical nuclear plant components.

At this time, it is fuel channels that provide the Corporation with its greatest challenges, both technically and economically. Given the hundreds of tubes in a reactor, the question facing the researcher is how to inspect them for the presence of cracks or defects without incurring immensely costly reactor downtime.

The NDE techniques developed at the Research Division have used CANDU's unique on-power refuelling capability to advantage. Three fuelling-based inspection systems, known at Hydro by their acronyms CIGAR, PIPE, and BLIP, were developed at the Research Division in concert with Central Production Services, Design and Development-Generation Divisions, and Canadian General Electric. The packaged inspection probe system (PIPE), which is used to inspect rolled joints in pressure tubes, was specifically developed to reduce reactor downtime since the standard system, channel inspection and gauging apparatus for reactors (CIGAR), took considerably longer to couple to a pressure tube. PIPE was developed as a response to an Atomic Energy Control Board (AECB) request that rolled joints in older reactors be inspected for delayed hydride cracking.

PIPE worked extremely well during the inspection of Bruce NGS Units 1 and 2. The system was used to inspect almost 300 rolled joints at close-to-design speeds. PIPE was an original and highly cost-effective solution to an urgent problem. At a typical downtime cost of \$10 000 per hour, the savings of PIPE over CIGAR amount to over \$12 million.

Hydride blisters form on pressure tubes when calandria tube to pressure tube contact occurs. A related concern is how to detect blisters before they become susceptible to cracking. Conventional techniques detect only the cracking not the blistering. Recently, a newly developed technology, which exploits innovative ultrasonic technology and advanced data handling techniques, was applied to perfect an uncracked blister detection module. A blister location inspection package (BLIP) using PIPE was used successfully to inspect pressure tubes in Pickering NGS Unit 4 reactor.

Debris and loose parts in the overall flow systems of nuclear power plants can be introduced inadvertently, particularly in the primary heat transport system, when the system is shut down and opened for routine maintenance. To remove the debris, and repair any resulting damage, requires draining the system, which in turn requires downtime. Downtime in turn necessitates buying replacement power, thereby putting pressure on the utility's finances.

All utilities in the U.S., France, Germany, and Japan have some form of regulatory requirement for on-line loose parts monitoring in their nuclear power plants. Ontario Hydro, although not required by legislation to provide such monitoring, does do so. The currently used system, however, has a major drawback; it requires regular auditory monitoring by highly trained personnel who verify signals as attributable to loose parts or debris.

Currently, the human ear is the most sensitive arbiter of whether these sounds are the result of metallic debris or of a process phenomenon such as cavitation. The need for specially and expensively trained personnel leaves stations vulnerable when these individuals leave for other postings.

The Research Division is addressing the problem differently, by means of neural network technology. Unlike the expert system approach to solving problems, which attempts to define the rules of logic used by the brain, the neural network approach emulates the function of neurons. Neural networks can be trained to learn a task, not merely to carry one out.

Neural networks are particularly adept at handling auditory signals, even when a well-defined set of rules about the character of the signals is unavailable. Already success has been achieved in applications where neural networks have demonstrated the ability to emulate some aspects of human hearing. Although sample space in these experiments has been small and the ratio of impact signal to background noise high, the technology would seem to go far to address the need for an automated loose parts monitoring system that obviates the need for costly training of personnel. No work is being done elsewhere on this particular application.

Ontario Hydro, accepting that no form of energy production is entirely environmentally benign, commits to design and execute its development plans in a way that ensures the continued vitality of the environment. The threat of global warming is one that not only Ontario Hydro, but utilities everywhere, must face, given that power production on the global scale releases to the atmosphere billions of tons of carbon dioxide and other gases.

As a responsible power producer committed to a sustainable environment, Ontario Hydro is acutely aware of its responsibilities in this area.

The principles of the greenhouse effect have been understood for over a century. A planet's climate is the product of a delicate balance of energy inputs, chemical processes, and physical phenomena. Some gases, like carbon dioxide and methane, tend to absorb heat in the same way that glass traps heat in a greenhouse, thereby allowing temperatures to build up. The intense heat of Venus is a result of an atmosphere composed mainly of carbon dioxide. Earth's atmosphere is quite different, being dominated by nitrogen and oxygen, whose physical properties do not contribute as hugely to global warming. The concentration of carbon dioxide has varied little over the past several million years, which has created a relatively stable climate conducive to life as we know it on our planet. The term "greenhouse effect" has become part of common parlance not because it is a new phenomenon, but because the industrial age has ushered in changes not all to humankind's benefit. Anthropomorphic activities necessary to fuel industrial production have increased the concentration of carbon dioxide and other so-called greenhouse gases to levels that could upset the delicate balance of the earth's atmosphere.

Not the least of these anthropomorphically generated threats to the stability of our planet are the by-products of world energy production. Fossil fuels provide almost four-fifths of the total world energy, and their use continues to grow at a rate of 3 percent annually. In North America, the Great Depression and two world wars reduced this amount somewhat, and the 1973 oil embargo reversed the trend significantly; however, since the mid-1980s emissions have been increasing. Reversing this trend and moving the world gradually away from this massive dependence on fossil fuels or at least dealing successfully with harmful emissions is essential to stabilizing the climate.

As a responsible power producer committed to a sustainable environment, the Corporation is acutely aware of its responsibilities in these areas. However, the problem must be clearly defined. Initial studies of the greenhouse effect have shown that identified changes have considerable uncertainty.

The Corporation, in an effort to resolve some of these uncertainties for Ontario, has been involved for some time in monitoring global programs. These programs have generated data, but many have properties that preclude the use of existing techniques of statistical analysis. Recognizing the need to develop methods that would result in the proper analysis of "noisy" data, the Research Division is currently developing trend analyses and prediction techniques with a view to identifying with greater certainty the emergence of any long-term trends in climate. These techniques when applied will allow detection and quantification of changes in temperature and precipitation across Ontario.

Global warming would have profound implications not only for the world as we know it, but also, on a much smaller scale, for its impact on Ontario Hydro's ability to do business. On the supply side, the availability of hydraulic generation could be either jeopardized or enhanced if patterns of precipitation and evapotranspiration were to be altered. Secondly, if further regulations were imposed to reduce greenhouse gas emissions, the fossil generation option would be further compromised. On the demand side, severe climatic changes could switch the peak demand from winter to summer. Another most significant impact would be that conventional future planning tools, which rely on historical climatic data, would become less reliable.



The Research Division's work on global warming to date is not painting as bleak a picture as might have been anticipated. The work to collect, to apply newly developed statistical techniques, and to compare this new data with approximately 100 years of global daily data is well underway. The comparison data are being obtained by Ontario Hydro's Power Systems Operation Division from the databases of the Canadian Atmospheric Environment Service. Another basis for comparison will be the data from the NASA Goddard Space Flight Center, which includes data from Russian records. In the global perspective, these data will allow comparisons that will contribute to the testing of scenarios obtained from simulations against real data.

The area being studied by the Research Division is bounded approximately by the 43° to 67° parallels, but emphasizes the area serviced by Ontario Hydro. This area is enough to determine if the magnitude of greenhouse-induced change is increasing with latitude, as predicted by global models. Examination of the data reveals that a slight increase of average yearly temperatures has occurred during the last decade. Warming increases with latitude and is of significance only in the northwestern portion of the province, where there are indications of earlier springs.

Options to resolve problems associated with burning

fossil fuels include the reduction of coal use, reduction of sulphur levels in coals, and the installation of emission control equipment.

Award-winning SONOX technology developed at the Research Division has resulted in an agreement with a major U.S. air pollution control firm that allows Ontario Hydro exclusive worldwide marketing rights.

Additionally, the timing of precipitation occurrences has shifted. Winter precipitation has decreased, and this coupled with earlier springs and warmer winters is expected to impact on the pattern of spring runoff. Once the obtained data have been thoroughly analyzed, concentration will shift to quantification of the implications of the data for hydraulic generation and electricity demand.

It has already been noted that one of the undesirable effects of burning fossil fuels is that the process adds to the concentration of greenhouse gases in the atmosphere. Burning fossil fuels also adds sulphur dioxide and nitrogen oxides to the atmosphere, which, in turn, contributes to a further environmental problem — the production of acid rain. In an effort to sustain the environmental base, Ontario Hydro is heavily committed to a comprehensive program to address this wide-ranging and complicated problem.

A number of approaches to problems associated with burning fossil fuels are being pursued by Ontario Hydro. The conversion of fossil fuels into a cleaner product is one of these. The development of an integrated gasification combined cycle turbine (IGCC) allows the use of lower cost coal rather than gas as a primary fuel. The IGCC conversion process integrates several proven processes, such as combined cycle and coal gasification, into a single high-efficiency, cleaner fossil option. Other options include the reduction of coal use, the reduction of sulphur levels in fuels, and the installation of emission control equipment.

A limestone slurry system will be installed on two units at Lambton TGS with an in-service date of 1994, and depending on load growth, more flue gas desulphurization systems will be installed at both Lambton and Nanticoke TGSs. A post-combustion acid gas emission control program designed to optimize high-efficiency scrubbing systems is underway. Results to date show that a limestone dual alkali process should perform as designed and that the production of commercial gypsum is technically feasible.

Another recent development is the SONOX process. This process uses a lime or limestone slurry with a nitrogen-based additive that allows the simultaneous removal of SO_2 and NO_x in one step. The slurry is injected directly into a furnace at temperatures between 900 and 1200°C. The technology achieves up to 85 percent SO_2 removal and effective NO_x removal of 63 to 80 percent. In some situations, the cost of installing and operating a SONOX can be as low as 50 percent of the cost of installing a wet flue gas desulphurization system. The technology won a New Business Ventures Excellence Award in 1989, and a major U.S. air pollution control firm has entered into an agreement with Ontario Hydro to establish exclusive worldwide marketing rights.

In the atmosphere, NO_x reacts with volatile organic compounds (VOCs) under action of sunlight to produce ozone and other photo-oxidants. Under specific weather conditions, photo-oxidants can reach levels thought to be harmful to human health, crops, and forests. The unusually hot and sunny summer of 1988 was conducive to photo-oxidant formation and ozone levels were at their highest in recent memory.

Whereas it is well known that ozone concentrations in the lower atmosphere depend on prevailing NO_x and VOC concentrations, the exact mechanism is complex and not fully understood. Southern Ontario is subject to some of the highest ozone concentrations in Canada. It is also known that the region is subjected to significant transboundary fluxes of ozone and its precursors. Additionally, a large number of sources, both natural and anthropogenic, are involved. At this time, it is difficult to specify with any certainty how ozone concentrations will respond to changes in NO_x emissions.

The Research Division has put into place a program, NO_x Emissions and Ozone Formation, which will generate information about Ontario Hydro's impact on ozone production. The work complements that being done in the U.K., Europe, the U.S., and by the Canadian federal and provincial governments and universities. Components of this program include an analysis of air quality; measurements of VOC concentrations, particularly of natural VOCs in air; measurement of NO_x emissions from soils; and modelling of the formation of ozone and other photo-oxidants in background air and power plant plumes.

Since the program started, achievements have been considerable. The concentrations of VOCs in air samples collected by Ontario Hydro have been determined in collaboration with Environment Canada, the Ontario Ministry of the Environment, and York University. A tethered balloon technique that can measure the vertical profiles of VOCs in the lower atmosphere has been developed. A method of measuring NO_x emissions from soils in situ is in use and is being compared with an alternate method developed for the laboratory. This allows a cheaper and more convenient means of measuring NO_x emissions from a wide range of soils.

Additionally, a photochemical box model is being used to interpret an extensive set of field measurements of VOCs made in Southern Ontario. Modelling indicates that natural VOCs play a significant role in local ozone formation. The work will help assess the role of Hydro's current operations.

Overall, what the Research Division is learning is that innovation must be considered a product to be marketed like any other. In a ruthlessly competitive technologically oriented global market, new technology is of little use unless it creates value. It is not only the senior manager, but also the researcher who must see how firmly wedded is the world of technology to the world of business. The inherent value of each to the other is high. Ontario Hydro's researchers are listening to senior management and responding to its questions: "How are the Corporation's needs changing?" "Where should we focus our resources?" "How can this discovery be turned to Corporate advantage?" "How can the gap between laboratory discovery and commercial implementation be shortened?" "What's out there in the scientific community that could help?" Only when the thrust of R&D is to answer these questions can laboratory discovery be linked to a company's overall mandate. Research and development are the levers. The strategies that can turn the best technology to Corporate advantage are dependent on management's attention and control.

Canada's harsh climate, always a challenge that must be met, has given rise to a study of the complex subject of ice forces on dams.

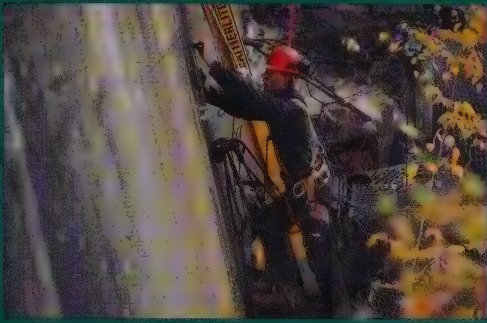
Ontario Hydro's generating stations are of three types: hydraulic, fossil, and nuclear. Fossil stations produce heat by burning either coal, oil, or natural gas. Nuclear stations use natural uranium in the CANDU reactor to generate heat. Both fossil and nuclear stations use the generated heat to produce steam, which in turn drives turbines. The remaining option, hydraulic, uses Ontario's water resources. The public does not always understand that, although Ontario has extensive water resources, not much of this water has enough drop or flow to make it suitable for hydraulic development. As it stands now, Ontario Hydro produces nearly four times as much electricity from sources other than hydraulic, and further hydraulic development, although a high Corporate priority, is necessarily limited.

During their 90-year lifespan, hydraulic stations require major repairs. The Civil Research Department contributes to the life extension of aging hydraulic stations through the Corporate Dam Structure and Turbine Upgrading Program, which provides state-of-the-art technological support to evaluate the integrity and to monitor the performance of Hydro's hydraulic stations. Programs run the gamut of the Civil discipline. One project improves dam safety by installing automated, remotely read instrumentation that can monitor critical geotechnical parameters in places as remote as the Abitibi Canyon. Another project seeks to determine the dynamic properties of foundation soils under conditions of seismic loading. Additionally, advanced monitoring systems were installed at Lower Notch GS and Manitou Falls GS to provide advance warning of abnormal behaviour attributable to dam deformation. Canada's harsh climate, always a challenge that must be met, has given rise to a close study of the complex subject of ice forces on dams and, over the past few years, to the development of polymer-based organic materials now used in transmission line foundation construction at subfreezing temperatures.

The Mechanical Research Department is also involved in the turbine upgrading program. To establish their structural integrity, turbine runners from six generating stations are being tested at twice their usual operating speed. The in-service dates of these runners ranged from 1904 to 1924. Additionally, a collaborative project being undertaken with the Canadian Electrical Association (CEA) will result in the provision of guidelines to Operations Branch on how to avoid bearing failures in hydraulic turbine generators.

The reliability of generators in Ontario Hydro's fossil-fired stations must be assured. Outage and repair costs can be enormous and can sometimes be avoided. Avoidable costs are incurred when a generator is either taken out of service because of a suspected problem that does not materialize or left in service with an unsuspected problem that subsequently leads to failure. To avoid these types of failures, the Research Division developed the generator expert monitoring system (GEMS), which is designed to help operators diagnose problems as they develop. The system was developed at the Research Division with funding from the Electric Power Research Institute (EPRI) and in cooperation with Design and Development-Generation Division, Nanticoke TGS, and SRI International. A GEMS prototype system, already in operation at Nanticoke TGS, is expected to prevent costly failures.

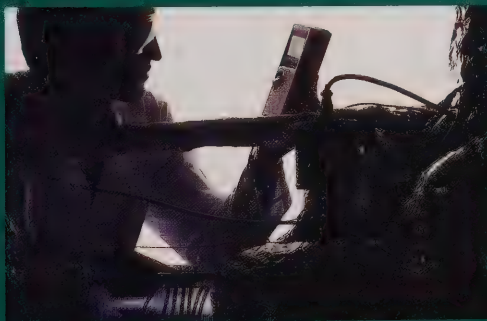
Another problem impacting on station reliability is attributable to minute breakdowns (partial discharges) within insulation systems. Partial discharges are symptomatic of aging and may be harbingers of a system's eventual failure. Only the most advanced instrumentation can distinguish these very weak signals, which might last only a nanosecond, from the high noise background typical of generating stations.



Even in places as remote as the Abitibi Canyon, remotely read monitoring instrumentation gives feedback about the dam's critical geotechnical parameters.



Laser isotope separation has the potential to greatly reduce the cost of heavy water, an essential component of the CANDU system.



Work is underway on a novel method of extracting tritium from the exhaust streams of fusion reactors. The work has both current and future applications.

State-of-the-art instrumentation, developed at the Division, has been in use for several years in hydraulic generators and has saved the Corporation many millions of dollars in avoided outage and repair costs. A comparable system for thermal station turbogenerators is in an advanced state of development, and prototype systems have been installed in three thermal stations. Additionally, partial discharge diagnostics is becoming increasingly important in relation to substation switchgear reliability.

Metallurgical Research Department's support of thermal generation is concerned primarily with life extension. This year's work involved the rehabilitation of Lakeview Units 5 and 6. In situ metallurgical evaluation was applied to determine the residual life of high-energy piping. Mechanical Research was also involved in this life extension program, and studies carried out at Lakeview TGS included an investigation of piping integrity, the development of systems designed for on-line monitoring of components, and the development of boiler tube assessment models. Additionally, extensive analytical work to determine the cause of failure of turbine blades at Nanticoke TGS has been completed. As a result, recommendations for modifying the design of these blades have been made.

Like other types of power plants, nuclear stations are susceptible to aging. Securing the high performance and safe operation of Ontario's nuclear stations is of paramount importance to Ontario Hydro's reliable and economic operation. Assurance of nuclear plant performance by means of nondestructive inspection techniques demands a comprehensive multidisciplinary approach; a heavy reliance on computer technology, signal processing, and electromechanical design is required to advance the sophistication of acoustic emission, eddy currents, ultrasonics, and spatial measurements technologies.

High technology applications of electromagnetics have provided short-term responses to problems occurring in operating reactors.

At this time, the Research Division is heavily involved in assuring CANDU fuel channel performance. Pressure tube studies include several projects designed to increase understanding of degradation mechanisms. Some of these are described at length in the earlier article "Leadership Through Innovation". Other programs involve making life assessments that allow informed decisions regarding fuel channel rehabilitation programs. This latter area of endeavour includes enhancement of the pressure tube creep deformation code, modelling of pressure tube hydride blister growth, and analysis of residual stresses in pressure tube rolled joints. The work on blister growth requires a detailed understanding of the sources and ingress routes of deuterium into the pressure tube material.

Studies are in progress to achieve end-of-life conditions in preservice zirconium niobium alloy, the material from which pressure tubes are made. In one program, zirconium niobium alloy is subjected to high neutron flux in reactors. Until recently, these tests were carried out in the DIDO reactor in the U.K. Since the closure of the DIDO reactor, alloy specimens have been transferred to France's OSIRIS reactor where the work continues. Results are providing the basis for ongoing research in many areas of the fuel channel program; changes in alloy microstructure that occur as a result of neutron bombardment can significantly affect the corrosion and fracture properties of pressure tubes, as well as their deformation rates. This type of work enabled the installation of a revised fuel channel creep code, called CDEPTH, to be installed in personal computers in Design & Construction and Production Branches.

Electrical Research Department is also involved in CANDU-related work. High technology applications of electromagnetics have provided short-term responses to problems occurring in operating reactors.

The most significant of these applications includes shock heating techniques for separating pressure tube and calandria rolled joints, which were used in the Pickering NGS Unit 1 and 2 retubing projects; the speedy development of an impulse current method to reposition garter springs in reactors; and more recently, the development of an alternating current technology that has enhanced the performance of spacer location and repositioning (SLAR) tooling. Costs avoided through these projects run into the hundreds of millions of dollars.

Experimental, analytical, and failure investigations of components that fail during their operational life comprise an important Research Division activity. This year, the Division provided valuable support when cracks were found in an operating Darlington NGS Unit 2 generator shaft. Metallurgical Research was called upon to conduct an exhaustive metallurgical analysis of one-half of the fracture surface to determine the cause of failure and the mechanism of crack progression. This materials analysis was complemented by a series of tests performed by Mechanical Research to determine cyclic stresses in the replacement rotor. Based on an evaluation of these stresses and an analysis of fatigue properties of the replacement rotor, all other operational rotors at Darlington NGS were modified to reduce areas of high stress concentration. To ensure that any stresses arising from machining and polishing were sufficiently small, a final step involved measuring residual stresses nondestructively by means of an x-ray diffraction technique.

Mechanical Research was also significantly involved when vibration levels of a primary heat transport pumpset exceeded warning and, in some cases, shutdown levels. The Department's timely intervention and provision of an advanced monitoring system enabled Research Division staff to reduce vibration to acceptable levels, thereby preventing a costly unit outage. Loss of power for other than safety reasons could not have been tolerated; at the time, electrical demand for the province had already exceeded system capacity.

Steam generators and other types of heat exchangers are also the focus of much attention in the nuclear generation program. To assure the reliable performance of steam generators, Chemical and Metallurgical Research Departments are gaining further understanding of corrosion mechanisms and providing strategies to prevent or mitigate them. Improving water chemistry, determining corrosion product transport mechanisms, understanding contaminant behaviour, characterizing the corrosion of materials under conditions of atypical water chemistry, such as are found beneath deposits, and defining the optimal water chemistry in preparation for station shutdown are only some facets of the current effort. The expertise gained over many years in the chemical cleaning of steam generators in thermal stations is being used to develop cleaning programs in nuclear plants.

Replacing heat exchangers as a result of corrosion damage involves considerable capital expense. The Chemical Research Department is exploring the role played generally by microbiological action attributable to the use of lakewater cooling methods. However, the recent invasion of the Great Lakes by zebra mussels is further increasing the risk of replacement. Consequent fouling of generator station intakes, heat exchangers, and internal freshwater systems has mandated a comprehensive research program designed to inhibit the organism's growth. A wide range of physical and chemical technologies are under intensive investigation, and research on mussel physiology is being done to provide an understanding of which preventive applications ensure optimal success. In the Civil Research Department, special methods of filtering intake water and subjecting the mussels to pressure are being evaluated for their usefulness. Preliminary laboratory work will be followed by in situ station tests.

This account of the Research Division's effort to help ensure the best performance of Hydro's nuclear generating stations is far from complete. Some safety-related studies should, however, not go unmentioned. Chemical Research is involved in an assessment of the degradation of nonmetallic materials in a service environment. Other safety-related studies added to an understanding of the formation, behaviour, and removal of radioactive aerosols and hydrogen in containment under postulated accident conditions

and performance evaluation of respirators, filters, and impregnated charcoal.

Issues impacting on worker safety generate research studies. Before the primary heat transport system of a reactor can be shut down, it must be decontaminated to reduce worker exposure to radiation. With a view to its improvement, the decontamination process is always under constant scrutiny. Chemical Research continues its involvement by developing improved reagent destruction methods and processes for removing peroxide- and oxygen-based antimony. Fundamental work on inhibitor mechanisms continues, as does more specific study of inhibitors for use at Bruce NGS. Additionally, during the scheduled Pickering NGS outage, an inspection of the vacuum building was carried out. An inspection of access ladders, platforms, restraint frames, horizontal lifelines, concrete anchors, and roof seals was conducted. The inspection revealed these components to be in excellent condition, with only a few anchorages and a negative pressure containment line requiring replacement.

Although much progress is being made toward understanding and managing age-related degradation of nuclear plant components, many issues require further understanding and further research and development (R&D). To aid the process, this year an integrated and comprehensive strategic plan on the subject has been prepared for CANDU Owners Group.

Polymer-based organic materials have been successfully developed and applied in transmission line foundation construction at subfreezing temperatures.

Hydro delivers the power produced by its 79 generating stations through a province-wide transmission and distribution network. The transmission system includes the transformer stations and other equipment that provide voltage regulation, switching facilities, and equipment protection. The delivery system is designed so that Hydro can manage fluctuations in power demand arising from adverse weather conditions, emergencies, and other unusual conditions.

Several interdisciplinary research programs support the upgrading of existing lines and stations. The Corporation's overhead transmission line refurbishment program has high priority. Over 27 000 circuit-km of transmission lines service the province. To ensure reliability, these lines, some of which have been in service since 1906, need upgrading. Through the refurbishment program, overhead ground wires are in the process of being systematically replaced through normal maintenance, and hardware and insulators are to be renewed. Aging towers, conductors, and concrete footings are additional components of the system that Research Division staff are assessing as part of the refurbishment program. Key achievements of this program are successful full-scale testing of towers in the field and the adaptation of a conductor corrosion device on lines up to 230 kV.

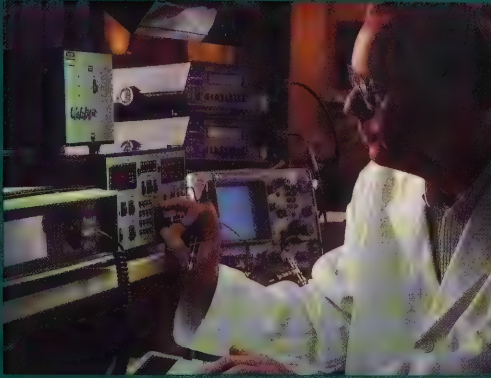
The definition phase of studies to determine the potential for refurbishment of older overhead transmission lines and their components is complete. New data were provided on the useful lives of foundations, towers, hardware, and conductors. Line refurbishment is found to be primarily dependent on conductor condition, since other components can be maintained or replaced, many without interrupting service. The average life of a conductor is approximately 65 years, considerable differences being evidenced in clean versus polluted regions. A plan to begin refurbishment has been approved.

A refurbishment rate of 400 circuit-km per year is necessary to eliminate conductors that exceed their forecast service life by the year 2010. Some lines requiring refurbishment are on narrow rights-of-way, which means the use of round stranded conductors would violate design practice. As a response, trapezoidal stranded conductors are being investigated to assess their reduced drag—and the corresponding reduced wind swing—which may allow their use on narrow rights-of-way.

Atmospheric processes directly affect the reliability and service life of equipment. Transmission line corrosion, particularly of conductors and towers, caused by airborne corrosive gases and aerosols, are studied in the Chemical Research Department with a view to developing a pollution climatology index and an environmental corrosion index, both of which could be used when planning refurbishment. Work continues on developing techniques to monitor and forecast the critical atmospheric conditions that lead to insulator flashovers on 500-kV lines during freezing rain and fog.

Reliable underground cabling is essential to a reliable delivery system. Reliability is affected by the degradation of polymeric cable insulation materials. The Chemical Research Department is establishing the mechanisms of polymer degradation and developing methods to assess their impact on service life. Civil Research is investigating the condition of thermal backfills in which old transmission cables are operating in Metropolitan Toronto. These projects will assist in planning the replacement or upgrading of aging cables and help ensure efficient operation.

Polymer-based organic materials have been successfully developed and applied in transmission line foundation construction at subfreezing temperatures. Because of costs, these materials are restricted to special applications. However, an attempt is being made to develop a modified cement-based material that will set, cure, and achieve full strength at low temperatures without the need for winter precautions.



Work performed in the Conductor Dynamics Laboratory has improved the reliability of overhead transmission lines by reducing conductor damage attributable to vibration and fatigue.



Power line carrier emissions from a transmission line are measured to determine the extent of interference to radionavigation beacons used by aircraft.

Metallurgical Research is studying the benefits that may be reaped from the use of conductors with improved creep properties. Such conductors could eliminate the steel core required in currently used conductors. A program to establish the creep properties of aluminum alloys and to determine whether these properties can be improved through modification of their metallurgical structure is in progress. Line hardware performance could also be improved with the use of better materials; for these applications, metal matrix composites look attractive. A collaborative program with the Canada Centre for Mineral and Energy Technology (CANMET) is in place, the objective of which is to develop components with superior properties.

Adverse weather conditions also wreak havoc on overhead transmission wires. Fibre-optic cored overhead ground wires (OPGW) are now being installed on all new transmission lines to build up a communications capability across the province. Designs of support hardware and different OPGW constructions are being subjected to fatigue cycles, i.e., simulated aeolian vibration due to wind, to provide assurance of their long-term reliability.

The transmission research program comprises only one-half of Ontario Hydro's delivery program. Distribution research, the other side of the delivery coin, is focused primarily on the development of techniques to improve safety and reliability of the power system delivery network.

A major portion of the delivery system consists of intricate distribution networks and the municipal utilities in the province. Since most power outages are caused by network failures (operating at voltages up to 27 000 V), a substantial effort has been devoted to distribution reliability and maintenance safety. As a result, the requirements for high-voltage fuses can be reduced by applying better fuse coordination guidelines. This change ultimately translates into savings of more than \$1 million per year for the Ontario Hydro retail system alone. In addition, in situ transformer tests now under development will reduce the risk of transformer failure.

A major concern in the distribution research area is the effect of Ontario's often adverse weather conditions on power delivery. The delivery of power from generating stations to customers involves the use of a system that has to maintain reliable service in a hostile environment. This is generally taken for granted, but depends on the development of many technologies fundamental to a secure system. For example, the vibration of lines caused by wind and ice accumulation manifests in many forms, most of which cause fatigue damage to the conductor as well as other forms of damage to hardware and structures. Field trials of devices to control galloping of distribution lines and bundle conductor transmission lines are continuing in Ontario and in other provinces under the auspices of a Canadian Electrical Association (CEA) program. To date, results show that galloping amplitudes on several classes of line can be reduced 70 to 80 percent by the addition of detuning pendulums.

The effects of lightning on the system are being studied to determine how best to cope with the hazards lightning creates. Additional sites have been selected to improve the efficiency of Ontario Hydro's severe weather forecast and detection system (SWORD). This advanced system provides data that enables power system operators to make informed decisions about high-risk areas and to minimize allocation of the replacement energy required to ensure reliable system operation during storms. To that same end, 50 feeder event recorders and two station event recorder systems have been developed and installed to provide data on the effects of lightning on distribution systems. This work will lead to better distribution equipment and standards, making it cheaper and easier to deal with lightning problems and to provide better distribution reliability.

The need for power system protection cannot be overstated. In the Electrical Research Department, a major innovation known as the programmable auxiliary logic controller/analog input module (PALC/AIM) system is a "universal" protection device that combines extreme versatility with ease of installation and application. Approximately 200 of these devices have already been installed. This move toward a new standardized approach to power system protection also lowers the cost of specifying, designing, and maintaining protection systems. In addition to

providing new protection systems, devices have also been developed for monitoring and control.

Eight power system disturbance recorders have been installed across Ontario to provide accurate monitoring of power system conditions following disturbances such as the sudden loss of a large generator. This information is crucial to enable system planners to specify the highest permitted operating limits possible without jeopardizing system stability. As well, the programmable synchrocheck relay adapted the synchronizing criteria to system operating conditions. The relay is an intelligent adaptive device that performs the "synchrocheck" function in transformer stations that have a variety of changeable configurations.

The application of power system stabilizers to advanced digital excitation systems, purchased for power plant life extension, and improvements in the tuning of existing power system stability controls have helped to relieve system operating constraints. Enhanced protection of power system components has contributed to unit availability. An in-depth analysis of the surge protection of generators is being carried out by Electrical Research under an Electric Power Research Institute (EPRI) contract. The analysis has provided a firm basis for selection of the most economical and effective surge protection schemes. At the same time, models developed for generators, transformers, and other system components have allowed computer programs used for system security assessment to be more precise, thereby improving our ability to maximize capability of the existing system without sacrificing system security.

By transferring technology to customers, the Research Division ensures that electrical efficiency improvements are realized as quickly as possible in the marketplace.

With seemingly endless discoveries of new applications for electricity, the public demand for energy continues to grow. Ontario Hydro is faced with the omnipresent threat of demand exceeding supply. Despite this pressure, the building of new facilities is being deferred while older facilities are being restored. Other strategies, however, exist to bring power demand in line with realistic supply options; one such strategy is Ontario Hydro's demand management program, which is designed to help customers use less electricity more efficiently.

The Research Division's Utilization Program is part of the Corporation's demand management strategy. By supporting the development of Energy Management Branch (EMB) programs and by transferring technology to customers, the Research Division ensures that electrical efficiency improvements are realized as quickly as possible in the marketplace.

In the past 2 years, EMB has launched a number of demand management programs based on the developments of the Research Division. Electrically efficient heat pump technology has been a high profile mandate for both the Research Division and the Corporation; space heating and cooling account for approximately 34 percent of electricity use in the residential sector. Development and field testing of the burner-assisted heat pump, undertaken by the Division in cooperation with its manufacturer, revealed the benefits inherent in this unique system. Quickly making use of Research Division's efforts, the Corporation advocated the transfer of the heat pump to its residential customers by offering a Corporate subsidy twice the amount of that offered for any other air source heat pump. Similarly, Ontario Hydro's promotion of ground source heat pumps resulted from province-wide field testing conducted by the Research Division. Ground source heat pump technology continues to advance; the pump's heat extraction and delivery system is being refined with the help of Civil Research's expert understanding of the ground's thermomechanical response. In support of the program, a further study is being done for the Canadian

Earth Energy Association. The study is exploring the phenomenon of ground ice formation, which could interfere with efficient operation of the pump.

The Research Division's Utilization Program contributions are by no means limited to heat pump technology. Research and development in the areas of water heating, building heat loss reduction, and appliance technology can result in extensive energy savings; consequently, this work has featured in the development of numerous demand management programs aimed specifically at the residential sector. For example, laboratory evaluation of the effects of insulation blankets and showerheads formed the technical basis for Ontario Hydro's recent "Water Heater Tune-Up" and "April Showers" promotions. Other EMB programs and pilots that have received considerable assistance from the Research Division include the window retrofit and basement upgrade programs, the "1000 House Study", and the "Laundering for Less" campaign.

Since 1982, over 130 companies have been involved in EMB's "Research Assistance Program", which transfers Research Division technology and provides technical support to Ontario industry. Ivex Industries is one satisfied customer; the company now employs infrared preheating of plastic film, a low capital cost retrofit that increased productivity by 25 percent and obviated the need for an expensive new production facility. In addition, the installation of a heat recovery heat pump at Casco Industries resulted in reduced energy consumption (equivalent to savings of \$64 000 per year) and merited a Canadian Electrical Association (CEA) energy efficiency award. Because recent statistics indicate that motors accounted for 73 percent of the industrial sector's electricity consumption, Hydro is targeting the promotion of high-efficiency and variable-speed motors and drives. To that end, a prototype portable motor-efficiency measurement system was developed by Mechanical Research specifically for EMB.

Past successes in the industrial "Research Assistance Program" guarantee a continued demand for research and development of energy-efficient technologies. Currently being investigated is the application of laser welding of copper in the computer industry.

The recent efforts of the Chemical Research Department have centred on an electrochemical testing and development facility (ETDF) commissioned this year. The facility is used to develop processes and to test electrodes on scales that will permit direct comparisons of commercial scale operations. The ETDF also evaluates chemical unit operations that industries could use to reduce electricity consumption.

It is a simple but accurate equation: efficient utilization of electricity directly translates into benefits to the environment. For example, a successful demand management program will reduce the consumption of fuels that can be harmful to the environment. This equation has been tested and proven by the recent work done at the Division. In an effort to improve the productivity of the metals- and minerals-producing industry, a process metallurgy project was initiated 3 years ago. The centrepiece of the project is a flexible electric furnace facility that, when used in collaboration with industry, optimizes electrical energy efficiency in metallurgical processes. Carried out with Falconbridge Limited, the first project involved developing an energy-efficient smelting method that ensured the compliance of Falconbridge's sulphur dioxide emissions with provincial government guidelines.

Work in the area of microwave technology continues. Commercial microwave equipment, boasting both high efficiency and lower maintenance costs, continues to be introduced to Ontario industry. The transfer of efficient microwave technology to industry is also advantageous to the environment; for example, microwave regeneration of activated charcoal allows the dry cleaning industry to recycle filters rather than consign them to landfill.

When demand and supply diverge, Ontario Hydro is faced with two options: creating more supply or reducing demand. The Research Division is strongly supporting the latter option and helping to reduce the effect of Hydro's operation on the environment, a contribution that cannot be minimized.



A novel high-performance water heater was developed to provide twice as much hot water, scald protection, and improved water quality as a conventional water heater. Significant demand management benefits will be achieved through widespread use.

In the area of environmental research and development (R&D), the Division supports Corporate efforts to assess the impact of its current and planned activities and to control emissions and wastes by the provision of new scientific knowledge and technologies. Additionally, technical support is given to different parts of the Corporation to allow the fulfillment of specific environmental goals. In 1990, a major activity was a review and a reorientation of the Division's research program on environmental impacts to ensure that issues of pressing public concern were being appropriately addressed.

There has been a steady and significant increase in public and government awareness of environmental concerns, particularly as they relate to human health. It is vital that Ontario Hydro test the truth of the assumption that exposure to electromagnetic fields is safe. Public concern has turned this into a major issue that impacts on Hydro's ability to construct new power lines. As a response, the Corporation has initiated an Electric and Magnetic Fields Risk Assessment Program (EMFRAP), which is determining the effects, if any, of public and occupational exposure to low-frequency magnetic fields. In addition to participating in the EMFRAP, the Chemical and Electrical Research Departments have initiated a long-term program in cooperation with academic institutions to investigate the interactions of electric and magnetic fields with biological systems and the biological responses of these fields. The objective is to gain the fundamental information needed to resolve the issue.

A recently completed rodent study showed no harmful effects of magnetic fields from computer screens, thereby casting serious doubts on earlier reports from Europe. Co-funded with IBM and carried out with the University of Toronto, this extensive study made use of special exposure facilities developed at the Research Division. The collaborative project and subsequent power-frequency research have contributed much to the Corporation's credibility in approaching the issue of public concern about the effects of magnetic and electric fields.

Environmental assessment (EA) requires would-be users of the ecosystem to assure the public that their proposals will not adversely affect the interests of future generations. The environmental effects of constructing and operating a generating facility are many. The Research Division is working to improve the ability of the EA process to protect the environment by providing better tools and more detailed knowledge with which to carry out the evaluation.

For example, current work involving radiotelemetry and sonar techniques can improve the efficiency of field studies on fish movement and population dynamics. Ways of studying the cumulative and cascading environmental effects of multiple hydraulic stations on river systems are being investigated; once understood, these effects can be prevented or mitigated.

Other research focuses on those contaminants principally associated with Ontario Hydro's activities. Research into oxidation rates of elemental tritium in the environment, uptake of radiocesium by fish, verification of atmospheric dispersion models, the role of NO_x emissions in regional ozone concentrations, and pollutant migration through soils are all examples of work in this area. Results are used in planning new facilities, developing operating strategies, and responding to and complying with government regulations; they also provide early indications of areas in which further R&D is needed for development of control technologies.

Chemicals used by the Corporation are a concern. The Corporation's goal of eventual elimination of herbicide use has significant ramifications for vegetation control on transmission and distribution rights-of-way. R&D is seeking alternatives to the expensive and hazardous manual and mechanical cutting techniques currently in use, with most effort being focused on the concept of natural "cover crops" that retard invasion of woody growth. In a related project, the environmental risk of the effective wood preservative pentachlorophenol is being assessed. A joint effort with universities is concentrating on the development of a leaching and biodegradation process for the disposal of pentapreserved poles.

Management of PCBs is being tackled head on at the Research Division, and compliance with Ministry of the Environment regulations can now be ensured.

Another unwanted by-product of power generation that has direct environmental effects is the audible noise produced by large station transformers and implosive conductor connectors. To ensure that environmental criteria governing sound emission levels are met, sound levels are monitored and, where appropriate, effective and economical sound-proof enclosures are being designed.

The Chemical Research Department is involved in the reduction of SO_2 and NO_x emissions. It reviews the limestone dual alkali (LSDA) absorber design and investigates the chemistry of the limestone regeneration process in a mini-pilot plant. Additionally, NO_x control and gypsum production from the limestone slurry and LSDA processes are being studied. Chemical Research also provides assistance for a planned demonstration of NO_x control through urea injection. Control of NO_x by means of reburning or staged combustion is also under evaluation for the Canadian Electrical Association (CEA). Meanwhile, the SONOX process that was developed by the Chemical Research Department has been accepted by Research-Cottrell for commercialization. The company is planning a number of full-scale demonstrations.

Management of PCBs is being tackled head-on by the Research Division. The Corporate PCB Destruction Task Force is chaired within the Chemical Research Department; the strategy developed includes a major research program on chemical destruction processes. Other work includes support and advice regarding a Corporate demonstration of capacitor retrofilling, on-site monitoring of out-of-province PCB incineration tests, and development of a better on-site PCB analysis technique. Compliance with Ministry of the Environment regulations can be ensured.

Due to increasingly stringent requirements for Ontario Hydro's coal ash disposal, the Civil Research Department is exploring economical and environmentally preferred techniques for ash management. Efforts include laboratory and field testing, as well as computer modelling. Static and dynamic leaching methods were developed for testing of fly ash from the Lambton and Nanticoke TGSs in order to ensure that no groundwater contamination occurs at these fly ash disposal sites. In an ongoing project, Ontario Hydro has successfully used large volumes of fly ash in structural fills, highway embankments, road base backfills, and land reclamation. In addition, the ash has been used for cement replacement in concrete and in the manufacture of cement and concrete products. The Civil Research Department continues to search for innovative fly ash utilization options.

Because nuclear generation will be an important supply option in the next century, nuclear waste is a significant public concern. The Civil Research Department has collaborated with the Mechanical Research Department in the development of the dry storage container (DSC) for the proposed irradiated fuel management system. The container, which has been designed to isolate irradiated fuel for a minimum of 500 years under conditions anticipated in a disposal vault constructed in plutonic rock, is featured as this year's Significant Research Contribution (see inside back cover). In support of this project, automated container welding and remote nondestructive inspection techniques are concurrently being developed by Metallurgical Research staff. Yet another project is characterizing operating wastes, developing waste volume reduction technologies, and determining waste performance under extended storage conditions.



To ensure the reliability and safety of future used fuel depositories, extensive testing is being carried out in the Underground Research Laboratory at Pinawa.



A major multidisciplinary study of ways to combat the effects of the zebra mussel invasion of Ontario Hydro's freshwater cooling systems is well underway.

Whereas the public is rightly concerned about the effects of Ontario Hydro's operations on the environment, it should also recognize that, on a daily basis, the Corporation must cope with factors within the environment itself that make the reliable delivery of power difficult. For example, a patented "SKRAM fishpulsar", an acoustic device developed by Research Division for controlling the movement of fish in the vicinity of generating facilities, is now being manufactured under licence for use by utilities and other organizations. Similarly, a major multidisciplinary study of ways to combat the effects of the zebra mussel invasion of Ontario Hydro's freshwater cooling systems is underway. Recent work shows that thermal and acoustic shock treatments may provide an environmentally friendly defense against the organism.

The harsh effects of climate and weather conditions on the transmission system, which result in degradation and corrosion, must be addressed to ensure reliable supply of energy. Projects that respond to this need are further addressed in the sections on the Delivery and Generation Programs.

The Divisional Projects Department (DPD) provides an interface between Research staff and groups internal and external to the Corporation. New technology initiatives, research management studies, and research business support comprise DPD's major products.

The Research Division seeks to leverage its resources and effectiveness by collaborating with external organizations. As part of this effort, departmental staff involved in new technology exert strong influences on Canadian universities and industrial research and development (R&D). The Division influences external organizations through the acceptance by Research Division staff of adjunct professorships at local universities and memberships on industrial advisory councils, such as the Canadian University-Industry Council for Advanced Ceramics, the Ontario Centre for Materials Research, and the Centre of Excellence in Laser and Lightwave Research. Also, DPD staff sit on Natural Sciences and Engineering Research Council committees and help direct and focus university curricula through council memberships.

To afford the Research Division greater flexibility in carrying out its mandate, Divisional Projects is committed to increasing the base of R&D expertise outside the Corporation. In support of Corporate long-range research, the Department organizes the annual Director's Fund competition and manages the Fund's eight ongoing projects. One Director's Fund program deals with the greenhouse effect and its impact on Ontario. Novel analysis of 100 years of weather data consistently shows that weather patterns have changed only over the past decade.

Divisional Projects looks at new energy technologies and assesses the viability of leading-edge discoveries, such as those relating to fusion and fuel cells. The Department also examines the information the Corporation needs before investing in devices such as large-scale combustion turbines and integrated gasification combined cycle (IGCC) turbines. With Ontario's major metals producers, the Department also plays a role in making energy utilization more effective. This work involves investigating current operations and future plans of metals producers and then evaluating whether these operations could be rendered more energy efficient. The results are collaborative research and paper studies.

A major area of study is looking at using oxygen to increase productivity and using electric arc furnaces for scrap melting. DPD is investigating ways to test and improve the effectiveness of Ontario Hydro's demand management efforts. Studies look at how residential customers perceive demand management options and determine which technologies are most acceptable to these customers.

Divisional Projects coordinates the production of the Research Division's 10-year business plan, which communicates future plans to senior management and provides direction to Divisional staff for detailed work planning. To support the Division's strategy-setting and business-planning activities, technology-forecasting activities are undertaken. Long-range planning forecasts are provided biennially for the strategy-setting and planning process. Forecasts are conducted to explore the probable development of specific technologies. Recent forecasts included assessing the impact of advanced industrial materials and high-temperature superconductors on Ontario Hydro.

One departmental responsibility is to identify opportunities to improve research management. The identification and reporting of "notable accomplishments" falls into this area. Notable accomplishments are R&D projects of significant benefit to the Corporation, to the customers of Ontario Hydro, or to some identifiable third party. Such reports are produced every 5 years and clearly demonstrate that the benefits provided by the Research Division significantly exceed its costs for that 5-year period.

Divisional Projects also carries out the very important Directorate support function, which includes general responsibilities such as assisting the Director with presentations and senior management meetings and, more specifically in 1990, with initiatives such as the modernization of the auditorium.

The Research Division Awards Program is the central means of fostering and rewarding excellence within the Division. DPD calls for nominations, orchestrates the selection process, and arranges the facilities for the presentation ceremony, which is usually held off-site.



Supporting research at local universities allows sharing of their sometimes unique capabilities and also encourages promising scientists to enter industrial research careers.

The Department continues to provide support in the area of external contracts. Activities include acting as liaison with Law and New Business Ventures Divisions; developing contracts and agreements and handling proposal requests; and producing and monitoring financial information. In a similar vein, patents are becoming a most important aspect of the Corporation's business; DPD has taken a leading role on the Patent Advisory Committee, thereby becoming a focal point for information on the patent process for the Division. In support of this external contract function, DPD monitors external publications for contracting opportunities. In addition, it maintains and updates information on the Division's capabilities in a number of externally-based databases.

Staff are also involved in the technical communications field. Perhaps the most important communication is the *Research Division Annual*. Research Publications Office staff write and assemble the text and coordinate the editorial activities, artwork, and printing. Another significant publication is the *Services and Capabilities* brochure, which describes the Division's R&D capabilities. This brochure is used extensively by other branches of Ontario Hydro in support of their marketing activities. The most recent publication, *Focus on R&D*, will be used as a guide for new employees and visitors to the Division. The publication offers a descriptive divisional overview. *Chit Chat*, the divisional newsletter, continues to play an important role in enhancing communication and boosting morale. Desktop publishing capabilities have enhanced the quality and significantly reduced the cost of all publications. These high-calibre communications have won a number of awards from organizations specializing in industrial technical communications. Finally, a report database, which has been under development for some time, is now functional; plans to transfer it to the ICE network have been initiated.

In addition to producing written communications, Divisional Projects is involved in the production of videos that describe the Division's activities. One such video, for visitors and new staff, has been produced this year, and another, which deals with the contribution of Ontario Hydro and the Research Division to the growth of Ontario, is in the early stages of production.

The Divisional Services Department continues to provide excellent service to the Research Division. This year, the services offered included business administration; financial reporting; payroll; records, space, and safety management; printing and clerical services; report production; model shop production; drafting; and photography. Additionally, significant strides have been made in the Integrated Computing Environment (ICE) project.

To enhance its specialized machining and prototyping capabilities, the Model Shop continues to upgrade equipment. From an equipment standpoint, efficient prototyping relies on a quick and accurate measurement capability. Versatile computerized numerical control (CNC) machines significantly help to achieve this end. A CNC milling machine, a CNC lathe, and two servo-positioning precision milling machines now complement standard machinery. The remaining non-numerical control milling machines and lathes are equipped with digital readouts on all axes.

From a design standpoint, shop personnel apply sound engineering practice and materials selection. Much of the Model Shop's work requires meeting the stringent requirements of clients that include CANDU Owners Group, Canadian Electrical Association, and Electric Power Research Institute. When submitting preliminary drawings, the customer has an opportunity to discuss optimized datum referencing, practical geometric dimensioning and tolerancing, and other cost-saving design considerations. Customers are further encouraged to test concepts quickly and imaginatively through simple prototype trials. In this way, clients can investigate isolated design alternatives and more quickly reach a final request with resultant savings on projects.

The ICE Section is responsible for providing computer and communications support to Research Division staff, who now use a site-wide local area network to improve productivity. Specific support areas provided by ICE include technical computing, computer communications, consultation, hardware/software support, and general problem solving. Network services include a central network computer server dedicated to "number crunching" applications, shared disk storage space where commonly required business/technical software applications reside, shared network printers providing report quality output, electronic mail services,

and network delivery of commercial, technical, and business database services on compact disk. This array of services promises to evolve to meet future client needs and new business goals. Combined with telephone answering and voice mail services, the ICE network is enhancing Divisional productivity.

The Drafting Section provides the Division with the best in illustration, design, and consultation for reports, presentations, and publications. Consistency, precision, and innovation each play an important role in customer satisfaction, and the office has maintained a high level of service through extensive use of MAC II technology. A TEKTRONIX colour printer has added a new dimension to artwork and visual displays. High-quality technical illustrations and posters, one of which won an achievement award from the Society for Technical Communication, are a hallmark of the Drafting Section.

The Photographic Services Section has had another challenging year. Contributions to major publications included the *1989 Research Annual Report*, the *1989/1990 Canadian Fusion Fuels Technology Program Annual Report*, the *1989 New Business Ventures Annual Report*, the *1989 Report to Employees*, and *Equinox*. Video productions included *Remote Robotic Weld Inspection* (a Research Division production), *Workplace Hazardous Materials Information System (WHMIS)*, a video training program (a Research Division production), and *CFFTP - Canadian Fusion Fuels Technology Program* (a CFFTP production). Investigation into a PC-based package that will greatly improve the storage and retrieval of all film and tape images is underway.

The Business Administration Section continues to operate at full capacity, with ongoing and new activities that utilize all staff resources. The Records Management program continues to evolve. In addition to the conversion of administrative files in the Division's various departments to the Corporate General Subject Index, summer students have played a key role in reviewing mountains of inactive files from Central Records. The Accounting Unit inherited additional responsibilities with the decentralization of the accounts receivable/billing activities from Corporate Accounting. The Unit will now be responsible for issuing approximately 500 to 600 invoices per year and for following up to ensure that payment is received.



The Integrated Computing Environment Project Group supports the technical and administrative computing requirements of Research Division staff.



In addition to administering expense reports, the Business Administration Section provides accounting, records management, and printing services to Research Division.

Information Management's commitment to providing secretarial and telecommunications support to the Division is unwavering. The Word Processing Centre provides a relief service by filling secretarial positions in the Division. Additionally, short-term clerical and filing help can be provided as required.

The Health & Safety Section ensures that line management provides a healthy and safe work environment. It also provides guidance to the technical sections on environmental matters relating to laboratory waste disposal, spill control, transportation of dangerous goods, and releases of hazardous substances into the environment. Legislative pressure and Corporate obligations have raised issues related to hazardous material management. Substantial departmental effort was directed at ensuring compliance with WHMIS legislation. To date, all chemicals in the Division have been inventoried and all laboratories have WHMIS boards and supplier material safety data sheets in place, as well as a set of workplace labels prepared for chemical containers. All Research staff have received WHMIS training, and a video-based training program is being completed for future use.

Considerable effort was spent to ensure the Division's compliance with the Corporate Code of Practice on Accident and Incident Reporting. Several incidents with medium and high potential for harm were investigated. Other major activities carried out by the Health & Safety Section were the initiation of hazard identification training, respiratory protection training, and workplace inspections.

Ontario Hydro's complex operation involves management systems and procedures, data and information handling, and equipment and materials. The Operations Research (OR) Department tackles these problems daily with a full range of mathematical and computational methodologies. The Department is one of the most active and effective industrial OR groups in North America.

In 1990, OR's client base and its range of services expanded. Services varied from informal consultations and short presentations to large-scale projects and tailor-made courses and seminars. The Operations & Decision Analysis Section employs sophisticated analytical methods to support Ontario Hydro's generation activities. Recently developed probabilistic performance models allow study of the effect of equipment maintenance on thermal station outage. At the request of Thermal Generation Division, the Section is examining the operating and outage data of coal pulverizers. Failure and downtime distributions are being developed for exploring alternative maintenance strategies. Once tested, the resultant model will be adapted to air and gas systems, generators, turbines, and other equipment.

Mathematical models are employed to improve hydraulic generation efficiency. A model was developed for optimizing the allocation of water to various generating units in hydraulic stations. The model's potential for increasing hydraulic output was demonstrated at the R.H. Saunders GS using historical data. In a simulation study carried out for the month of January 1989, the model produced 641 MWh of additional energy. If applied to all hydraulic stations, the increase in energy production could be substantial. A pilot expert system for improving nuclear fuelling has been completed, and a production version of the system is being contemplated.

All these models and systems may expand energy output at lower costs. Examples include risk analysis in support of turbine blade replacement and decision analysis of alternatives for design and construction management systems.

Given the Corporation's need to exercise financial restraint, novel approaches must be applied to enhance management effectiveness. To that end, projects are

underway to develop performance indicators for supplying materials to two nuclear generating stations and to creating a manpower planning model for electrical inspection. In addition, Energy Management Branch (EMB) receives analytical support for its demand management mandate. EMB must reduce energy consumption by promoting end-use technology. The Operations & Decision Analysis Section assisted in prioritization and trade-off analysis of EMB programs and developed user-friendly models and databases for the efficient storage, retrieval, and analysis of information.

The environment is a high-profile issue at Ontario Hydro. The Department provides technical support to the environmental program through mathematical modelling and applications of information technology. A computerized emission reporting system has been developed to meet the Ministry of Environment's Municipal and Industrial Strategy for Abatement (MISA) requirements along with models to assess the environmental impact of Hydro's operations.

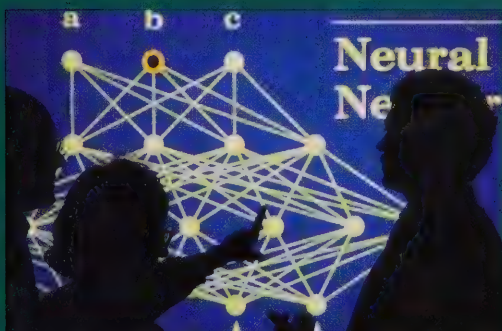
Accurate reliability predictions for power systems and their constituent parts comprise a most important engineering task. The Reliability Unit is at the forefront of a worldwide effort to develop more advanced tools. Production Branch requested deterministic and stochastic modelling of river inflow forecasts to optimize energy production from hydraulic generating stations. This year an important research project to develop a probabilistic approach to the dynamic stability and security of power systems was initiated. This approach is to be combined with existing techniques to provide a more complete reliability methodology.

Through publications and participation on committees and in conferences, the Reliability Unit enhances its international reputation. This year, staff participated in a number of international activities and served on an Institute of Electrical and Electronics Engineers committee. Members of the Unit provide an advisory function to several Electric Power Research Institute projects.

Selection and analysis of data for technical or management studies often appear straightforward. However, when data are scarce, interrelated, dispersed, or even contradictory, drawing valid conclusions



A group of statistical consultants engage in discussion, but there will be consensus before the report goes out.



Neural network technology is being used to solve a variety of pattern recognition and signal processing problems.

requires the advanced statistical analysis offered by the Statistical Methods & Analysis Unit. Studies in 1990 included probabilistic modelling of crack initiation in pressure tubes; analysis of public opinion questionnaires for the Demand/Supply Plan; and comparison of performance indices of system protection devices. Additionally, the Unit assisted Hydro in preparing statistical forecasting models for the Ontario Energy Board hearings.

At the request of the Nuclear Generating Division, the Statistical Methods & Analysis Unit studied the relationship between the operating expenditure and performance of a CANDU reactor. A probabilistic model relating the capability factor (CbF) to operation, maintenance, and administration (OM&A) spending was developed. It was found that reactor aging necessitates higher OM&A spending, and that increasing OM&A spending can improve CbF performance in diminishing increments. This model has been adapted to reactors in the United States and used to help set public utility rates.

Recent advances in computer and information technology, particularly in the areas of artificial intelligence and database management, presented the OR Department with new challenges; in 1990, the Advanced Computational Methods Unit was created to meet these challenges. The Unit is devising a system for the creation, maintenance, and use of hypertext applications. Neural network technology will be used to investigate several pattern recognition and signal processing problems, including the analysis of hydroacoustic sonar signals to identify and speciate fish and the interpretation of acoustic signals obtained from monitoring loose parts in the primary heat transport system of CANDU systems.

Externally, the OR Department continues to be involved with universities, professional associations, and research institutes. Staff hold adjunct professorships and serve as executives or committee members with international professional societies or research granting agencies.

Chemical Research Department

The Chemical Research Department provides the Corporation with a technical resource that includes process and materials chemistry, corrosion chemistry, chemical analysis, biology, and environmental science. The areas of interest and expertise in the Department are wide and reflect the diverse chemical aspects of modern power generation. Specialized experimental facilities and state-of-the-art instrumentation for measuring and analyzing experimental parameters are used in departmental investigations. Comprehensive chemical analytical services, which support the research programs of the Division as well as the Corporation, are also offered. Work ranges from routine testing to research and development contributions that advance knowledge throughout the field. The Department is divided into six sections.

Civil Research Department

The Civil Research Department has been a leader in civil engineering technology for over seven decades. Departmental expertise, which includes key areas such as concrete technology and quality assurance, provides vital support in the construction of new facilities. Specialized geotechnical engineering support is also provided to the Division and the Corporation. Research and development projects have ranged in time and scope from the construction of Ontario Hydro's early hydraulic stations to the construction of a modern world-class power project, the Darlington Nuclear Generating Station. The Department also provides research, development, testing, and inspection services in all aspects of soil and rock sciences for both Ontario Hydro and external clients. Researchers are involved in developing and promoting the application of improved materials and practices for the civil discipline. The Department is divided into three sections.

Divisional Projects Department

The Divisional Projects Department creates and maintains connections between various groups within the Division, within the Corporation, and external to the Corporation. The Department is engaged in two major areas of work, as follows: (1) interdisciplinary research, which includes external research projects and the Director's Fund projects and (2) research management, which includes technology forecasting, business support, research management support, directorate support, and research publications.

Divisional Services Department

The Divisional Services Department is responsible for providing a variety of clerical and technical services to the engineering and scientific departments within the Research Division. Emphasis is placed on meeting the operating and business needs of the Division effectively and efficiently and on ensuring reliable functional and administrative support for Division staff. Services offered include report production; business administration; financial reporting; records, space, and safety management; printing and clerical services; model shop production; drafting; photography; payroll; and computer communication support. The Department has eight diversified sections.

Electrical Research Department

The Electrical Research Department performs research, development, and testing for the Corporation and provides technical expertise in the broad areas of power system technology, power equipment, electronics, communications, and demand management techniques. The Department strives to improve the production, transmission, distribution, and utilization of electricity. Selected areas of the natural sciences and nuclear engineering are researched, and environmental studies related to the transmission and distribution of power are conducted. The Department performs technical studies that relate to renewable energy sources and energy conservation. Researchers forecast and fulfill needs for new technology, innovation, and technical expertise to solve problems on the power system and for customers of the Corporation. In its programs, the Department cooperates with external organizations in the solution of problems common to electric utilities. Electrical Research comprises seven sections.

Mechanical Research Department

The Mechanical Research Department provides research and development resources and experimental and specialized testing facilities in the mechanical discipline. The Department's mission is to improve the performance, reliability, and safety of materials, components, and processes used in the generation and transmission of electricity and energy. To verify safe and reliable behaviour of equipment, structures, and components, both modelling and full-scale tests are used. The Department also plays a leading role in coordinating the Research Division's contribution to developing methods of dealing with containment and immobilization of used fuel. It also concentrates on developing safe methods to store, transport, and ultimately dispose of high- and low-level nuclear wastes. Staff have earned an international reputation for extensive, leading-edge research in fall protection and the development of fall protection systems. Mechanical Research is divided into four sections.

Metallurgical Research Department

The Metallurgical Research Department provides research, development, technical services, and specialized testing facilities in the disciplines of physical metallurgy, process metallurgy, and materials science. The overall thrust of these activities is to ensure a safe and reliable supply of electrical energy and to improve the efficiency of its utilization. In pursuit of these goals, the Department deals with characteristics of materials performance and with correlation of both design intent and actual service behaviour. The majority of the Department's work program is focused toward support of CANDU technology and toward ensuring the reliability of Ontario Hydro's nuclear and coal-burning plants. At the same time, recognition is given to issues that impact on economic, environmental, and demand management. The Metallurgical Research Department is composed of five sections.

Operations Research Department

The Operations Research Department provides consulting services to all units of Ontario Hydro in the fields of operations research, mathematics, and statistics. Members of the Department organize courses, workshops, and seminars in all of these disciplines. The Department simultaneously carries out research in power system reliability. Always ready to offer applied research support when unusual and complex operational and strategic issues arise, staff use a full range of state-of-the-art mathematical and computational methodologies to arrive at workable solutions. Queries run the gamut from those related to management systems and procedures, through those concerning data and information handling, to problems related to equipment and materials. The Department is composed of one section and three units.

Mike Bell (Electrical Research) was elected to the Advisory Board of the International Heat Pump Centre of the International Energy Agency. The Board guides the activities of the Centre, which is located at NOVEM in the Netherlands. Mike represents the International Power Utility Heat Pump Committee and provides the Centre with the electric utility perspective.

Steve Oda and Ibrahim Balbaa (Electrical Research) received the 1990 Canadian Committee on Electrotechnologies (CCE) Innovation Award. The award was presented for their development of a hybrid microwave-electric resistance kiln to process advanced ceramics. Steve was also elected to the Board of Governors of the International Microwave Power Institute (IMPI) in recognition of the Utilization Section's involvement in industrial microwave and radiofrequency heating applications.

Maier Perlman (Electrical Research) was nominated a Fellow of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). ASHRAE is one of the largest international engineering societies with over 50 000 members. Maier served for 3 years as chairman of an ASHRAE technical committee (service water heating).

The Canadian Industrial Laser Association (CILA) has instituted elections, which resulted in Jim O'Neill (Electrical Research) being acclaimed President and Len Mannik (Electrical Research) being elected to its Board of Directors.

Richard Sauvé and Jim Tulk (Mechanical Research) were awarded a New Technology Award for their contribution to the development of a Tritiated Heavy Water Transport System. Richard was involved in the analysis and design of the new transport system, and Jim conducted licensing drop tests to verify the system's structural performance under impact conditions.

Nayan Shah and Robert Zane (Mechanical Research) received a Director's Award for their development of a rocket-assisted impact system for impact testing of radioactive waste transportation containers. The system successfully simulated a collision between a locomotive travelling at 65 mph and the proposed irradiated fuel transport container (IFTC).

Jim Tulk and Dimitrios Taralis (Mechanical Research) and PK Mukherjee and Jim Sato (Civil Research) were awarded a New Technology Award for their contribution to the development of the dry storage container (DSC) for the dry storage of nuclear fuel. Savings to Hydro total over \$80 million in capital costs.

In recognition of his work on conductor galloping and other forms of line vibration, Dave Havard was selected as secretary of a CIGRE (Conference on Large Electrical Systems) study committee (overhead lines), and of a working group (mechanical behaviour of conductors and fittings). CIGRE is the leading technical organization that promotes exchange of information on electrical power systems research.

Mat Cenanovic (Electrical Research) accepted an appointment as an Adjunct Associate Professor of Electrical Engineering at the University of Windsor for the period September 1, 1990 to August 31, 1993. His responsibilities will include research, development, and transfer of novel electromagnetic technologies to industry through the cooperation of Ontario Hydro, the University of Windsor, and industry.

George Anders (Electrical Research) received a New Technology Award for his contribution to the development of advanced optimizing techniques for power cable system design and operation. These techniques were embedded in a set of user-friendly cable analysis programs (CAP). CAP is a package of five software programs that analyzes steady state and transient behaviour of electric power cables.

Bert Vanderglas and Doug Scarth (Metallurgical Research) won a New Technology Award for contributing to the development of a leak-before-break technology for CANDU piping systems. The technology was applied to the design of Darlington's heat transport system. As a result, safety requirements relating to catastrophic failure of large diameter piping can be met more economically. In February 1990, the Atomic Energy Control Board (AECB) approved the design for use at Darlington NGS Unit 2.

Gary Ford and Mark Vainberg (Electrical Research) received a New Technology Award for contributing to the development of probabilistic methods and computer programs for use in transmission station design assessments. These methods make it possible to show that a higher short circuit capability exists at some older stations than was originally believed.

The 1989 Research Division W.P. Dobson Award was awarded to Chris Cheh and Ron Massey (Chemical Research) for their contribution to the development and implementation of a gas chromatographic method for separating hydrogen isotopes. The innovation attracted international recognition and earned significant financial rewards for the Corporation.

Mark Tinkler, Scott McNabb, Ken Yiu, and Murray Mathers (Metallurgical Research) and Gil Poon (formerly of Metallurgical Research, now Production Branch) won the 1989 H.A. Smith Award for their development and field demonstration of a portable robotic system for in situ repair of cavitation damage to hydraulic turbine runners.

Al Donner (Metallurgical Research) was awarded a 1989 Director's Award for his contribution to the development of innovative experimental facilities relating to loss of coolant accident (LOCA) simulations. Al's role was to develop experimental techniques and to construct apparatus.

Krish Radhakrishna, KC Lau, Bob Dowdell, and Bob Watts (Civil Research) were winners of a 1989 Director's Award for their contribution to nuclear waste disposal research. The work attracted international acclaim and successfully resolved crucial questions relating to the design of waste disposal vaults.

Ray Marttila (Electrical Research) won a 1989 Director's Award for his contribution to the development of power system protection systems. Ray was instrumental in developing novel techniques for the analysis of impedance-based protection systems; the theory for the first system to completely protect the stator winding on thermal units; and the theory and subsequent implementation of a universal directional relay aid in the protection of heavily loaded lines.

Craig Simpson (Divisional Projects) won the Presidential Award of the Canadian University-Industry Council of Advanced Ceramics (CUICAC). The award was for his contribution to the growth and well-being of the organization. Craig also served as chairman of CUICAC's Business and Finance Committee.

Miriam Mozes and Rene Mangal (Chemical Research) were awarded a 1989 New Business Ventures Excellence Award for contributing to Ontario Hydro's international business. The SONOX process, which can be used for controlling SO₂ and NO_x emissions in power plant flue gases, was invented by Miriam Mozes, Rene Mangal, and Raja Thampi.

John Kuffel (Electrical Research) was awarded a 1989 New Business Ventures Award for his proposal to design, procure, and commission a high-voltage test laboratory for the Jordanian Electricity Authority. Unfortunately, the proposal was deferred due to federal budget cuts. Nevertheless, NBV recognized John's efforts and those of team members Ernie Jones and Jack Edgar.

The publications produced in the Research Publications Office continue to attract the attention of the Society for Technical Communication (STC). Last year, the *Services and Capabilities* brochure won the Distinguished Award, the *Research Annual* and *Chit Chat* awards of excellence for writing and design, and the series of bookmarks, *Hydrolines*, was recognized by an Award of Achievement. Drafting's input into the *Research Annual*, in the form of technical art, also received an Achievement award. The STC is the largest professional organization devoted to the arts and sciences of technical communication.

Occupational Classification of Staff

Management & Professional (324)

Technicians & Technologists (253)

Support Staff (71)

0 50 100 150 200 250 300 350 400 450

Total costs including those for space, materials, equipment, and work done (\$M)

Research Division OM&A (37.7)

Revenue from work for other organizations (4.2)

Transfers to other Ontario Hydro Branches (39.2)

0 5 10 15 20 25 30 35

Proportions of Research Division Costs for

Various Categories of Work (% of Total Costs)

Testing (12)

Consultation (4)

Technical Investigation (12)

Research & Development, Current Needs (35)

Research & Development, Future Needs (19)

General (18)

0 5 10 15 20 25 30 35 40 45 50 55

Research Cost Breakdown

by Major Resource Categories (% of Gross Costs)

Salary and Benefits (57)

Indirect Costs (20)

Direct Costs to Projects (23)

0 5 10 15 20 25 30 35 40 45 50 55

Research Division's Major Programs:

Proportions by Actual Gross (%) Costs for 1990

Utilization (8)

Provides research and development (R&D), technological innovation, and technical support to improve power utilization.

Electric Power Systems (6)

Enhances operating efficiency and reliability of the bulk power system in the areas of generator and system controls, system protection, machine diagnostics, instrumentation, and reliability assessment.

Transmission (12)

Provides technological support and innovation directed toward improving the reliability of existing stations and lines.

Distribution Systems (4)

Provides innovations to improve Ontario's distribution and retail delivery systems.

Nuclear Generation (33)

Provides R&D in support of the continued efficient, reliable, and safe operation of Ontario Hydro's nuclear generating units.

Nuclear Waste (4)

Provides R&D to ensure the safe, long-term management of Ontario Hydro's nuclear wastes.

Thermal Generation (5)

Provides R&D to assist the fossil-fuelled generating stations maintain and extend their reliable and efficient operation and helps them meet environmental regulations.

Hydraulic Generation (2)

Provides R&D to ensure the continued efficient operation of hydraulic generating stations.

Environmental Impact (6)

Provides a scientific understanding of the effects of Ontario Hydro's operations on the natural environment.

General Research (13)

Provides general technical services to the Corporation in operations research, materials and equipment testing, and chemical analysis.

External Research Support (3)

Provides the Corporation with timely access to leading edge technology by involvement in collaborative R&D and support of external research organizations.

Human Resource Development (4)

Maintains and develops the capability of the Research Division staff to perform work at a high performance level.



AECB	Atomic Energy Control Board	GEMS	Generator Expert Monitoring System
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers	GIS	Gas-Insulated Switchgear
BLIP	Blister Location Inspection Package	ICE	Integrated Computing Environment
CANDU	Canadian Deuterium Uranium (reactors)	IEEE	Institute of Electrical and Electronics Engineers
CANMET	Canada Centre for Mineral and Energy Technology	IFTC	Irradiated Fuel Transport Container
CAP	Cable Analysis Programs	IGCC	Integrated Gasification Combined Cycle
CbF	Capability Factor	IMPI	International Microwave Power Institute
CCE	Canadian Committee on Electrotechnologies	LOCA	Loss of Coolant Accident
CEA	Canadian Electrical Association	LSDA	Limestone Dual Alkali
CFFTP	Canadian Fusion Fuels Technology Program	MISA	Municipal and Industrial Strategy for Abatement
CIGAR	Channel Inspection and Gauging Apparatus for Reactors	NDE	Nondestructive Evaluation
CIGRE	Conference on Large Electrical Systems	NSERC	Natural Sciences and Engineering Research Council
CILA	Canadian Industrial Laser Association	OM&A	Operation, Maintenance, and Administration
CNC	Computerized Numerical Control	OPGW	Fibre-optic Cored Overhead Ground Wires
CUICAC	Canadian University-Industry Council of Advanced Ceramics	OR	Operations Research
DPD	Divisional Projects Department	PALC/AIM	Programmable Auxiliary Logic Controller/Analog Input Module
DSC	Dry Storage Container	PIPE	Packaged Inspection Probe (system)
EA	Environmental Assessment	R&D	Research and Development
EMB	Energy Management Branch	SLAR	Spacer Location and Repositioning
EMFRAP	Electric and Magnetic Fields Risk Assessment Program	STC	Society for Technical Communication
EPRI	Electric Power Research Institute	SWORD	Severe Weather Forecast and Detection System
ETDF	Electrochemical Testing and Development Facility	TLRP	Transmission Line Refurbishment Program
		VOCs	Volatile Organic Compounds
		WHMIS	Workplace Hazardous Materials Information System
		XIPD	X-ray Induced Partial Discharge (system)

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Significant Research Contribution

Ontario Hydro is developing a dry storage container (DSC) for the interim on-site storage and eventual transportation of used fuel from the Pickering NGS to future off-site disposal facilities. The Research Division is providing technical support to the Nuclear Engineering Department to ensure that the container can safely fulfill this purpose. Research and development (R&D) support has been considerable; enough to merit the program's choice as the 1990 Research Annual's Significant Research Contribution.

The DSC is essentially a double-walled steel container that utilizes reinforced high-density concrete, for strength and radiation shielding. A lid of similar construction is welded to the container. Civil Research Department developed and tested the concrete to optimize the density and high strength needed for radiation shielding and structural integrity. Coatings to protect the steel from corrosion and to facilitate decontamination procedures are being developed in the Chemical Research Department. Metallurgical Research Department performed extensive testing to assess various welding processes, inspection techniques, and remote welding technology. This work will assist in the selection of the most suitable weld joint design and in the preparation of technical specifications for the lid closure welding system and facility to be installed at Pickering NGS.

Mechanical Research Department took on the responsibility of performing the required AECB licensing tests. To meet the transportation requirements, the container must be able to survive severe impact followed by exposure to intense fire without escape of radioactive material or gases. To reduce costs, scale models were constructed, and these were extensively tested to gain an understanding of the container's performance.

AECB transportation regulations specify that the DSC be subjected to a minimum of two drops: one from a height of 9 m onto a flat, unyielding surface, and another from 1 m onto a solid steel bar projection. During the tests, accelerometers measured the impact acceleration of the container's body, and strain gauges the outer surface strain. The DSC was tested between drops for cracks and leakage. Additionally, analytical modelling was developed to emulate the container's structural integrity during impact. Drop test results from the quarter-scale model have been compared to analytical results to validate the structural response of the full-scale DSC.

Fire testing of the quarter-scale model was carried out by igniting the DSC with kerosene and engulfing it in flames for 30 minutes at 800°C. Temperature and pressure measurements as a function of time were taken both during and after the fire test for a period of 23 hours. Fire test results demonstrated that the integrity of the DSC model was maintained and that the DSC survived postulated accident conditions.

Half-scale drop tests similar to those performed on the quarter-scale model are scheduled during 1991. These tests will be crucial to attaining the AECB Design Approval Certificate.



The development of the DSC involved many experts from several disciplines within Ontario Hydro. Here at Babcock & Wilcox's fabrication plant in Cambridge, where the half-scale model was assembled, are some of the Research Division team members (from left to right) Jack Lee, Dimitrios Taralis, P K Mukherjee, and Peter Maak.

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